EVALUATION OF MEASURES FOR REDUCING PM_{10}-CONCENTRATIONS IN URBAN AREAS

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ABSTRACT

High urban concentrations of PM_{10} are a well-known problem in many European countries. PM monitoring stations in Austria show very high concentrations of PM_{10} especially in alpine basins. The PM10 daily mean threshold value (50 µg/m³) is frequently exceeded. Hence, there is a need for introducing measures in order to reduce PM_{10} concentrations in urban areas.
Based on detailed emission inventories dispersion modelling was carried out for the Lavanttal region, a basin south of the Alps with rather unfavourable dispersion conditions. The results provide important information about the source attribution of PM_{10} concentrations. Compared to measured concentrations the simulated total PM_{10} load agrees within +/- 2,5 µg/m³. In addition the results give an idea how effective measures should be formulated.

1. INTRODUCTION

The EU directive 1999/30/EC defines the standards for air quality in the European Community. The Immissionsschutzgesetz Luft (IG-L) is the realisation of this EU-directive into national law. In 2001 threshold values for PM_{10} were implemented. Austria chose to implement more stringent threshold values than given in the EU directive. While the threshold for the annual mean value (40 µg/m³) and the daily mean value (50 µg/m³) remains the same, the acceptable number of days with violations of the threshold for the daily mean value has been reduced from 35 (EU) to 30 and shall decrease further to 25 starting in 2010.
Measurements indicate that the permissible number of days with threshold violations is exceeded by far those of 30/25 throughout Austria. In particular, unfavourable meteorological conditions at the south side of the Alps result in the fact that even in small urban agglomerations PM_{10} is a major problem in air pollution.
In the year 2005 the threshold value for the annual mean value was exceeded in Austria on two locations only, whereas the daily mean value was exceeded more often than the allowed 30 times on 58 of the 111 PM_{10} monitoring stations in Austria. Not only urban areas are concerned, violations occur even in rural areas.
The reasons for the high PM_{10} burden are various. Local and regional emissions combined with unfavourable dispersion conditions are of importance in some regions while in others the transboundary pollution mainly from easterly and south-easterly directions is the crucial factor. Especially the basins in the central Alps as well as on the south side of the Alps are affected by unfavourable dispersion conditions with low winds, strong inversions during wintertime and little precipitation.
This high number of violations of the air quality (AQ) standard calls for an action plan with massive restrictions in order to achieve the limit values given.
As PM_{10} emissions have various sources the impact of all these possible sources have to be considered within an abatement programme. Therefore, all sources have to be known and represented in a good emissions inventory, which is the basis for dispersion simulation with an adequate model.

2. METHODOLOGY

The approach for evaluating the impact of different sources on the air quality and for quantifying the effects of some abatement measures is based on the application of a high level emission inventory combined with a dispersion model.

Emission inventory

The emission inventory is the basis for all quantification activities. Hence, it is imperative that a high quality in source description is required. The high quality concerns quantification as well as temporal and special allocation.

Traffic exhaust emissions are calculated by the Network Emission Model (NEMO), which combines a detailed simulation of the fleet composition and emission factors for various engine types and engine load conditions depending on the traffic situation, fleet composition and the road network (Rexeis et al. 2005).

Dispersion modelling

GRAL (Lagrangian dispersion model, Oettl et al. 2003a and Oettl et al. 2003b) is a combined model system for the calculation of prognostic steady-state wind fields and dispersion. It was developed especially for the application to dispersion situations with low wind speeds in complex terrain. In the following paragraph the basics of the wind field simulation and of the algorithm used for dealing with low wind conditions in GRAL are briefly described.

For the flow field modelling a meteorological approach based on wind statistics and stability is used. First, a pre-processing of local meteorological measurements, of about one year is carried out. Thereafter a statistical classification of flow situations into wind sectors J, wind speed categories K and stability classes L (usually 3) from a single point observation in the domain is carried out. Finally, J x K x L = N steady state simulations with wind field model GRAMM (Graz Mesoscale Model, see Almbauer et al. 2000 and Oettl 2000 for more details) are carried out. Main features of GRAMM are prognostic non-hydrostatic wind fields, terrain following grid (tetrahedronal grid), implicit time integration, parameterizations to account for low wind conditions, constant surface cooling in stable conditions (10 W/m²), spatial variable surface heat flux in convective conditions (shadowing effects of topography).

The dispersion calculations are carried out with GRAL using the calculated flow fields. During low wind speed conditions large horizontal atmospheric motions develop (so called meandering), which influence the dispersion process significantly. The Lagrangian model used applies an algorithm accounting for the effect of stronger turbulences in low-wind weather situations.

The input data from the emission inventory consists of different source types with different release characteristics. As a consequence it is necessary to simulate these different kinds of sources like line sources, point sources and tunnel portals, simultaneously. GRAL fulfils these requirements and the following parameters are taken into account for the individual source types:

- Point sources: location (3D): Source strengths, exit velocity, temperature differences, source diameter.
- Line sources: location (3D, also bridges): Widths, source strengths, heights of noise barriers.
- Area sources: Same as line sources.
- Tunnel portals: Location (3D), source strengths, exit velocity, temperature differences, traffic influence on tunnel jet (Oettl et al. 2002).

The formation of secondary organic and inorganic aerosol as well as long-range transboundary PM is currently not considered in the model simulations.

Quality assurance

Quality assurance of the modelling system GRAL is guaranteed by permanent validation activities using data from field experiments. Currently 18 different data sets for tunnel portals, point sources, line sources and built-up area are used for the model evaluation, such as Prairie Grass, Indianapolis, INEL, Elimaeki, Goettingerstrasse, Hornsgatan, etc. Model development and modelling results have been published frequently in peer-reviewed journals (e.g. Oettl et al. 2001, Oettl et al. 2003a/b).

3. RESULTS AND DISCUSSION

An intensive study was carried out to determine the share of different PM_{10} emission sources in the region of Klagenfurt (in the framework of the EU-Life project KAPA-GS (http://www.kapags.at)) and in the Lavanttal. Measurements were combined with numerical simulations and partly also with chemical analyses.

The numerical simulations - based on emission inventories and dispersion calculations - enable a clear distinction between the different sources. PM_{10} measurements and some available chemical analyses of PM_{10} samples were used for a validation of the model system. This approach has been applied to the city of Klagenfurt and to the Lavanttal. The main results from the latter are briefly presented here.

The Lavanttal region is a basin with an extension of 30 x 20 km² surrounded by mountains 1400 m – 1800 m higher than the valley floor. Major emitters in that region are a paper and pulp mill, the small city of Wolfsberg (pop. 26000 / 57000 with suburbs and commuters) and agricultural activities. Traffic is dominated by a highway and some minor roads.

Besides the two big industrial facilities (pulp and paper mill and wood industry) this region is mainly dominated by small enterprises and agricultural activities. Nevertheless, PM_{10} is a problem concerning the AQ standard for the 50 µg/m³ threshold for the daily mean value. The PM_{10} AQ standard (50 µg/m³) is exceeded 35 – 68 days per year. Therefore, a detailed emission analysis was carried out. In contrast to urban locations in this case emissions from farming play an important role. On the basis of the available data only emissions from land cultivation (e.g. ploughing, harrowing) were taken into consideration, emissions from life stock were excluded.

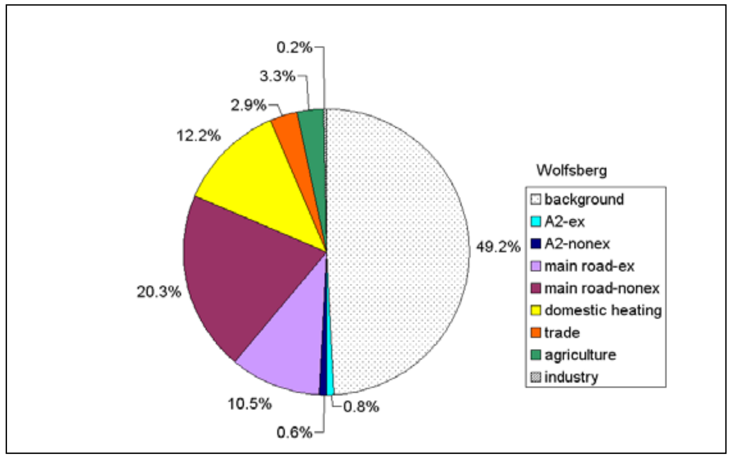

Figure 1: Contribution of the different sources to the PM10 emissions in Wolfsberg, Lavanttal.

Figure 1 shows the contributions of the different source categories in Wolfsberg. Traffic exhaust and non-exhaust are dominating, industry and trade also have a remarkably share. Domestic heating also has a relatively high share as in the rural areas wood is still a major energy source. During wintertime traffic non-exhaust is three to four times more important than traffic exhaust.

The background accounts for about 50 % of PM_{10} within this analysis. In this case background was determined by measurements taken from a monitoring station within the calculation domain, but at a higher altitude location. The annual mean value at that station amounts to 17 µg/m³. Adding this value to the calculated ones results in a good agreement between calculation and measurement at the remaining three monitoring locations.

We attribute secondary formed PM and transport on larger scales as the major source processes to explain the background. In (almost) all environmental assessment studies made at our institute the background is between 17 and 24 µg/m³. In contrast, simulations of NO_x are traffic dominated and show a residuum of less than 15 %.

In Figure 2 the annual mean value of PM_{10} (including background) in the Lavanttal is shown. The area inside the thick blue line depicts the region in which the Austrian PM10 standard for 2010 (25 days threshold value exceeded) would be violated. Such areas have to be declared as PM_{10} non-attainment zones. In such zones abatement measures have to be set by law.

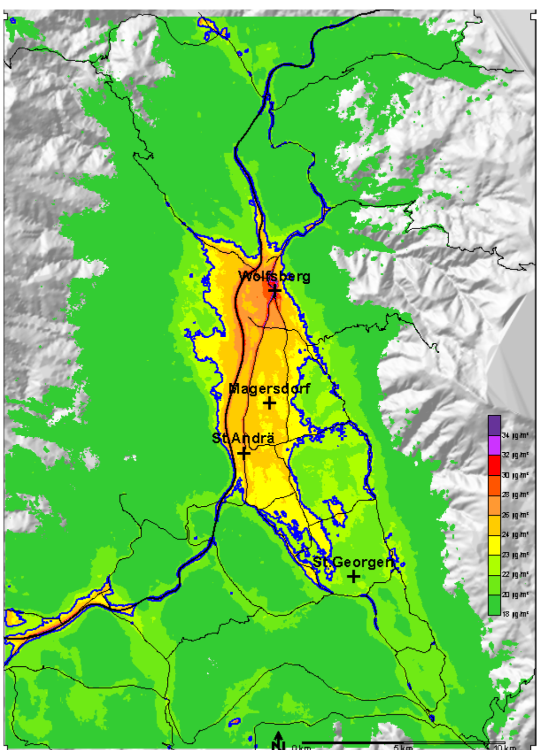

Figure 2: PM10 concentrations [µg/m³], all sources, annual mean value.

The potential of several measures for the reduction of the PM10 concentrations, which were considered as feasibly by the local authorities, was investigated. These measures were defined as follows:

- Scenario 1: Improvements in winter service due to enforcement of de-icing instead of sanding
- Scenario 2: Reduction of domestic heating emissions by 50% due to usage of district heating

- Scenario 3: Retrofitting of all diesel cars with PM filters with an efficiency of 90%

An improvement in winter service (scenario 1) helps to reduce the PM emissions by more than 10 tons per year. However, the area with threshold violations would be reduced by 5% only. A reduction in domestic heating emissions (scenario 2) by 50% (i.e. by almost 47 tons) would result in a reduction of almost 43% in the area concerned. The retrofitting of diesel cars with PM filters would minimise the PM emissions by approximately 6 tons per year. However, the effect on the area concerned is almost negligible.
It has to be mentioned that even a combination of possible measures (reduction in emissions from domestic heating, winter service and retrofitting of diesel cars with PM filters) would not ensure that the air quality goals can be met.

4. CONCLUSIONS

Dispersion simulation with the model system GRAL offers the possibility to calculate differentiated air quality inventories on the basis of detailed emission inventories. As many different source types with their special emission characteristics are simulated simultaneously, their contributions to the total PM_{10} load can be determined. The analysis in the Lavanttal showed that in rural areas domestic heating and agricultural emissions are dominating, whereas even in small cities traffic exhaust and non exhaust emissions have more influence. Nevertheless, the background concentration accounts for up to 50 % of the measured concentrations. The calculated results were compared with observed concentrations and an agreement within +/- 10 % was found.
The calculated results show that in a large region the Austrian PM_{10} standard for 2010 (25 days with threshold value exceeded) would be violated. Therefore it is necessary to introduce PM_{10} source abatement measures. Short term measures (concerning traffic) show rather little effect, as they often lead to a relocation of traffic emissions instead of reducing them. Reducing emissions of domestic heating by 50 % would reduce the area affected by violations of the AQ standards by almost 45 %.
Before introducing any abatement measure in regions, which do not reach the Austrian AQ standards it is important to identify the source contribution of the total PM load. Especially in South alpine basins the complex terrain and the often occurring low wind conditions state a challenge for dispersion modelling. Nevertheless, the model system GRAL is a useful tool for defining effective measures.

5. ACKNOWLEDGEMENTS

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