Comparison of concentration predictions, done by different modellers for the same street canyon (Podbi-Exercise)

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1 Introduction

For many Environmental Impact Analyses street level pollution modelling has to be done. The models have to be quality assured, this includes the demand, that the result of a calculation must not depend on the model used. But even if several persons use the same model, they will not get the same result as shown, for example, in the EMU project (Robins et al., 2000). The present paper describes the "Podbi Exercise", where different persons of several institutions used different models (the operational models they normally use in their institutions) to predict the concentrations in the street canyon Podbielskistrasse in Hannover. The aim was, to get hints of the magnitude of the variation in the results and in the procedures, and also clues on how to improve the situation, because the same air pollution limit values are established all over the European Union but the procedures to predict these air pollutions are different and there is only weak information about the variations in the results.

2 Procedure

The comparison was done for an existing street canyon with heavy traffic, where no concentration measurements existed but where measurements were intended to be executed. Input data like traffic parameters, meteorology and background concentrations were known in a quality, as usual for practical projects to be done within a limited time but it was scheduled to do additional measurements. The exercise was done in 2 phases. Phase 1: The participants did the calculations with the input data, available at the beginning of the project. They did not know each other and did not know the results of each other. After evaluation of the results, all participants met in a workshop and compared their procedures and results. They got informations about the results of higher quality additional meteorological and traffic parameter measurements and the first preliminary results of the concentration measurements in the field, all done by the Lower Saxony State Agency for Ecology (NLOE). Phase 2: The participants repeated the calculations, using the updated informations and the increase of knowledge gained during the workshop. These results were evaluated and then discussed during a second workshop.
The invitation to take part in the exercise was published in several German journals, announced in the internet and during several conferences. At first it was thought to do the exercise in the German speaking modeller community with all data and communications in German, but on the basis of TRAPOS as a platform, a couple of months later an additional comparison on an English language basis was done at an European scale. The present paper only deals with that first German speaking group, which is finished now. 11 institutions took part with 14 different models. Three participants used wind tunnel measurements and 11 used numerical models. Seven different numerical models were used.

At the beginning of the study, the input parameters, necessary for the exercise, were available in the internet (http://www.lohmeyer.de/modellvergleicheng/) together with forms for a structured submitting of the results for a summarising evaluation by Lohmeyer Consulting Engineers (LOH), the co-ordinator. The participants of the exercise were asked to calculate the annual means of benzene, soot and NO_2 as well as the 98-percentile of NO_2. But they were not only asked for the final results (the concentrations) but also for the results of the single phases to come to these final results as for example applied emission factors, details of model set up and procedure, calculated dilution factors etc., see below. Additional data, available in the course of the exercise and a section for the latest news was available in the internet. It took nearly 2 years from the provision of the data for phase 1 in the internet (Jan. 1999) to the presentation of the final report of the exercise in Nov. 2000. For the full report, participating institutions and models used, but without correlation between institution, model and result, see Baechlin et al. (2000), downloadable from the publications section in http://bwplus.fzk.de.

3 Results

The participants had no serious variations in their input concerning meteorological data and background concentration, as these data were given as an input.
Determination of the emission of the streets was already more difficult. To do that, one needs the traffic volume. As input data for phase 1 the results of traffic counts were given, done in the period 1987 - 1995 between 6.30 o'clock AM and 6.30 o'clock PM. For the average daily traffic volume in 1999, some of the participants just used the number as it was given, others increased the number to account for the fact, that the counting was only done for a limited number of hours during the day, some participants even increased the number to account for the fact, that the counting was done some years ago and the concentration prediction had to be done for 1999. Thus the traffic volume, used by the participants, ranged from ca 16 000 to nearly 25 000 vehicles/day, that is a difference of ca 50%. Another number needed is the emission factor of the vehicles, that is the air pollutant emission per VKT (vehicle and kilometre travelled). As an example see in Fig. 1 the numbers used by the participants for the benzene emission factors for passenger cars, they range from less than 0.02 g/VKT up to more than 0.06 g/VKT, a difference of more than a factor of 3.
Another difference concerning the emissions occurred for example in their representation in the models. Some of the numerical models contain 3 dimensional digital models of the built up area under consideration where the emissions of the Podbielskistrasse and of 2 adjacent streets (Ferd.-Wallbrecht-Strasse and Boedeckerstrasse) had to be represented. Fig. 2 shows that this was done in

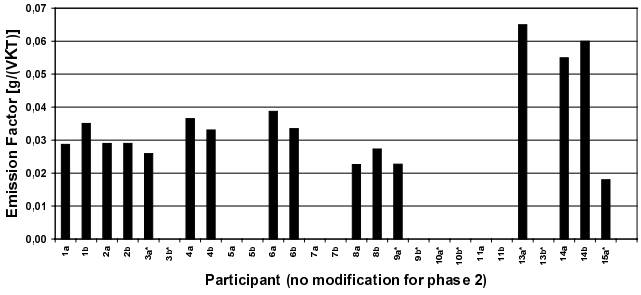

Fig. 1 Benzene emission factors used by the participants, a = phase 1, b = phase 2.

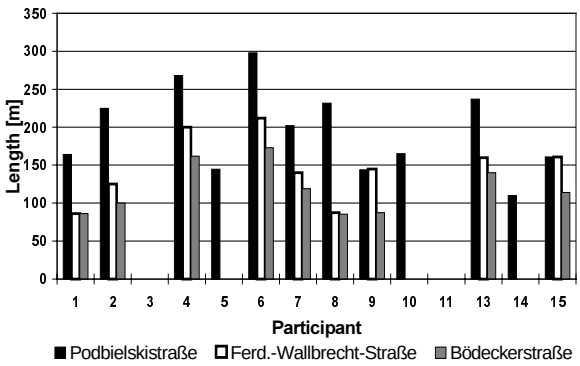

Fig. 2 Source lengths, represented in the digital building models.

different ways: to determine the additional concentration by the street, where

$$c_{total} = c_{additional\ by\ street} + c_{background}$$

some participants represented Podbielskistrasse in their models with lengths of less than 150 m, another participant with a length of nearly 300 m, that is more than a factor of 2 difference. The other streets were also represented with different lengths, some models only consider Podbielskistrasse itself.
Large variations showed up in the dilution, calculated by the participants between the emission on the road and the monitoring station on the pedestrian walkway. It was asked to hand in the dimensionless concentration c* at the position of the monitoring station as a function of the wind direction. The parameter c* is defined as $c^*=c \cdot u_{100} \cdot H/q$ with c= concentration, u_{100}= windspeed 100 m above ground, H= building height = 25m as a convention for this exercise and q= emission density. Fig. 3 shows the results. Large variations can be noticed between the participants, partly there is even more difference than a factor of 3.

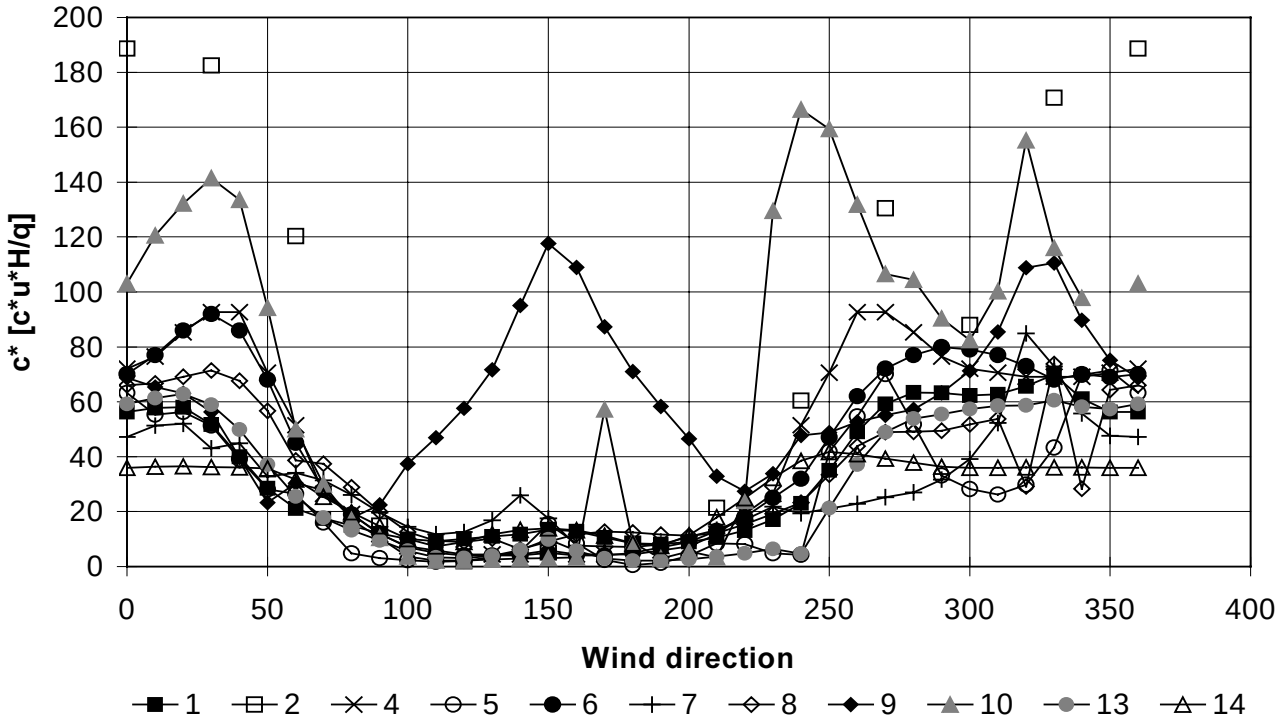

Fig. 3 Variations of the c* values (dilution parameters) applied by the participants.

As described above, all the single phases and procedures of the participants were investigated before the evaluation of the calculated total concentrations was made, which was compared among the participants and also to the results of the field measurements. An example for the results is given with Fig. 4 for the annual mean of benzene and Fig. 5 for the annual mean of NO_2. For benzene, after phase 1, the difference in the predictions is up to a factor of 2, which is unexpectedly low, compared to the differences, seen in the single phases towards the final result of the calculation. After phase 2 the difference reduces to less than a factor of 1.5 with values between 4 and 6 $\mu g/m^3$ which is well inside the confidence interval of the field measurements. For NO_2, after phase 1, the difference in the predictions is larger than a factor of 2 but mainly by the results of 2 of the participants, after phase 2 the difference reduces to less than a factor of 2, and it would be far less than 2 without one of the participants who predicted the highest value. This participant is outside the confidence interval of the field measurements but the other participants are well inside.

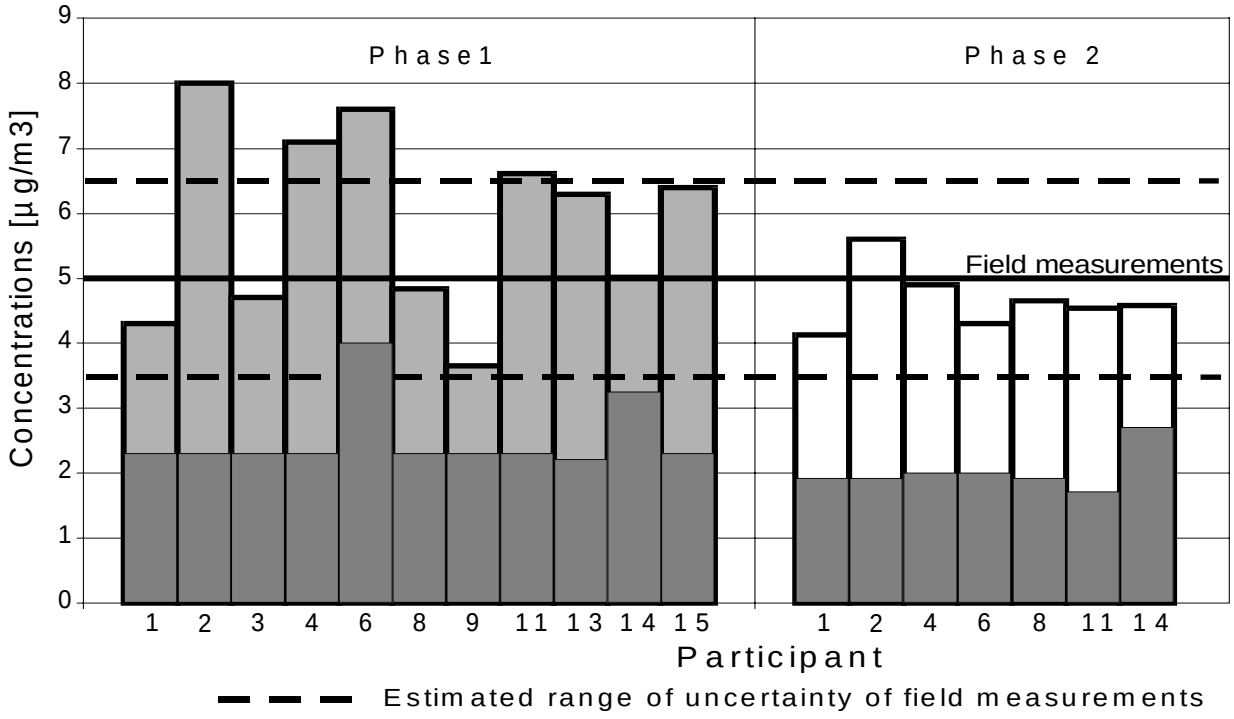

Fig. 4 Comparison of the calculated annual mean of the total concentration for benzene to each other and to the results of the field measurements. Lower part of columns are the background concentrations taken into account.

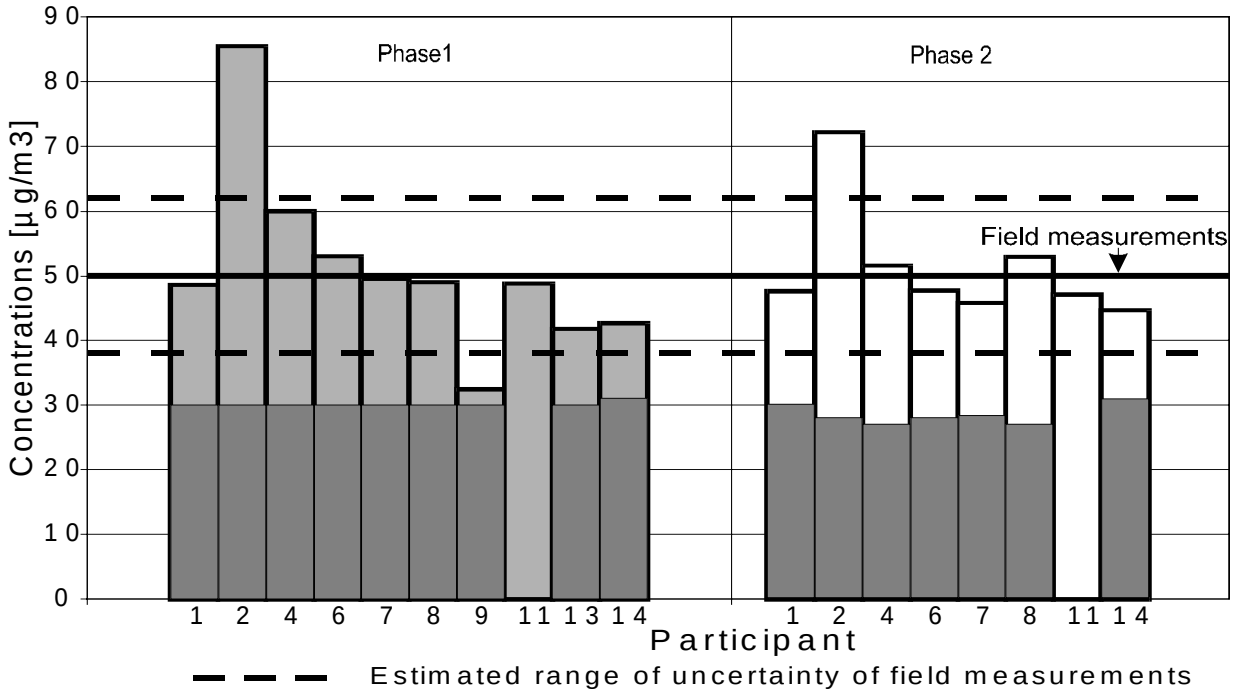

Fig. 5 Comparison of the calculated annual mean of the total concentration for NO_2 to each other and to the results of the field measurements. Lower part of columns are the background concentrations taken into account. Participant 11 delivered no values for background concentration.

4 Conclusions

Concentrating on the points in the street canyon, which are the hardest to handle but which are the points to consider for the execution of the EU Air Quality Directives, the exercise showed:

- there is no standard procedure how to do this kind of street level pollution modelling,
- the use of different tools for the different steps yields different results,
- it is important who does the modelling and how, even for a given model,
- for the emission modelling the results differ by a factor of 3,
- for the dispersion modelling the results differ by a factor > 3
- the results for the total concentrations yield variations by a factor > 2, but the final differences of the prediction of the total concentrations at the points under consideration are less than expected on the basis of the variations in the emission- and dispersion modelling,
- the quality of the calculated concentrations depends on the quality of the input data

Based on these findings we recommend:

- Not only the final results of the determination of the concentrations are important, but also the results of the emission- and dispersion modelling should be consistent for the different participants. The participants should continue their collaboration to find out the reason for the variances in the emission- and dispersion modelling and they should work on a reduction of these variances. May be more guidance has to be given to do that sort of prediction and standardisation might also be needed.
- The results of concentration modelling should not be given as a fixed number but with a range of uncertainty. Guidance has to be developed and introduced how to quantify that uncertainty.
- Users (incl. scientists) should take part in ring tests such as Podbi - Exercise.
- Authorities might support that last point by introducing into calls for tenders as condition, that they will accept only offers of institutions which took part in such ring tests.

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