QUALITY CONTROL IN DISPERSION MODELING:
Validation of a screening model for PM10 and NO_2

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Overview

European air quality guidelines require gathering information about air quality at locations where the population is affected or possibly affected by high concentrations. High concentrations are often found in densely built up streets with high traffic loads. In order to identify hot spots and to assess possible measures to improve the situation, screening models are widely applied in current air quality planning.

Besides accomplishable data requirements, the main request for such models is to produce reliable results. The screening model IMMIS^{luft} is being widely applied througout Germany to assess air quality in cities. The validation of the model has recently been updated in a study based on measurement data from North Rhine Westphalia.

The data sets used for the model validation are being described and it is shown that the model is adequate for its task together with the limits of its application. Furthermore the issue of deriving reliable NO_2 values based on NOx is addressed.

Screening model

The screening model IMMIS^{luft} was implemented to calculate traffic-induced air pollution in urban streets. It is based on the CPB model for street canyons and a box model for open building structures.

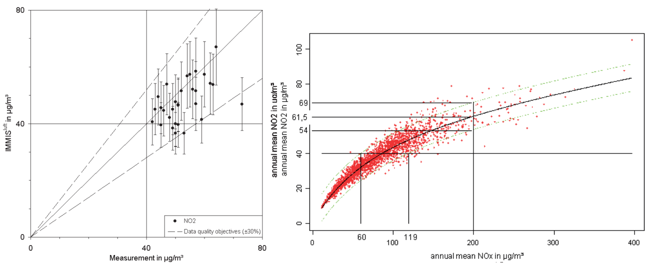
Input data for validation

- 15 traffic-related measurement stations
- Measurements available for the years 2003 to 2005
- 33 datasets for the annual mean value of NO_2
- 35 datasets for the annual mean value and the daily limit value of PM10
- traffic data including the fleet composition based on:
  - traffic censuses from clean air management and action planning or
  - state wide emission inventory of road traffic

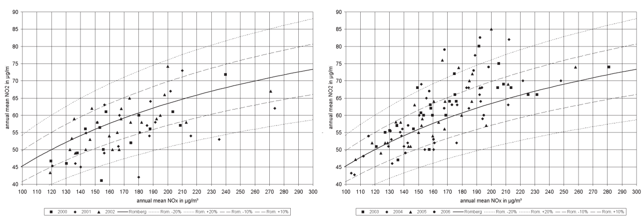
Deriving NO_2 from NOx

Models which do not account explicitly for photochemical processes generally derive NO_2 concentrations by calculating the NOx annual mean values and estimating the NO_2 values from NOx using statistical approaches (e. g. Romberg approach). Such approaches are based on the evaluation of measured NO_2/NO-relationships.

In recent years, it has been observed that while NOx emissions were reduced considerably, NO_2 concentrations decreased only slightly or even increased. Inspection of the available data revealed that new exhaust emissions reduction technologies, namely the emission standards Euro 3 and higher for diesel passenger cars, result in NOx emissions containing several times as much NO_2 as petrol engine cars and diesel engine cars with older emission standards . These increased NO_2 direct emissions are so far not considered with statistical approaches which may lead to underestimated NO_2 results. While the earlier values are reasonably well described, the latter values are generally underestimated with the Romberg approach.



Left: Scatter plot comparing measured (x-axis) and modelled (y-axis) annual mean values for NO_2 (2006). Dashed lines indicate data-quality objectives for NO_2 as defined in Directive 1999/30/EC, Annex VIII. Annual limit value of 40 μgm^{-3} for NO_2 is marked. Model results are displayed with an error bar of 20 %. Right: NO_2 versus NOx annual mean values 1956 – 1998 for urban measurement sites. Black line represents regression function deriving NO_2 annual mean value from NOx. Dashed lines indicate 95 % prediction interval.



NO_2 versus NOx annual mean values for stations in Germany (exceedance of 40 μgm^{-3} only). Black line represents Romberg-Lohmeyer function. Dashed lines indicate 10 %, dotted lines 20 % error margin. Left: Data 2000 – 2002. Right: Data 2003 – 2006.

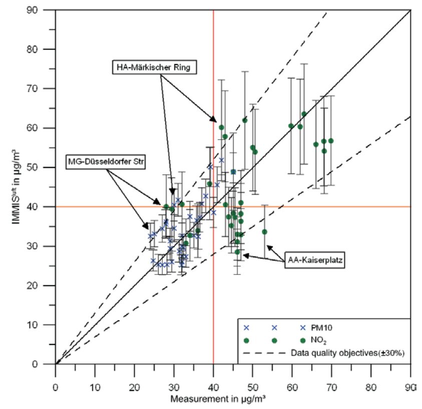
Validation results

Hit rates

A hit is counted either if a measured limit value exceedance is predicted correctly with IMMIS^{luft} or if the measured and the modelled value comply with the limit value. The hit rate is the ratio of hits to the total number of examined situations. The table to the right summarises the hit rates for NO_2 and PM10 for the annual limit value of 40 μgm^{-3} considering an error tolerance of 20 % for NO_2 and 10 % for PM10 as shown in the figure to the right. Additionally, the table gives the hit rates for the PM10 annual mean of 32 μgm^{-3} which indicates that the allowed number of daily means above 50 μgm^{-3} is most probably exceeded.

Hit rates for the investigated years and the annual limit values of 40 μgm^{-3} for NO_2 and PM10 and for the annual mean value of 32 μgm^{-3} for PM10. Error tolerances of 20 % for NO_2 and 10 % for PM10 are considered.

Year	NO_2 (40 μgm^{-3})	PM10 (40 μgm^{-3})	PM10 (32 μgm^{-3})
2003	78 %	89 %	67 %
2004	77 %	86 %	64 %
2005	82 %	83 %	83 %
2003-2005	79 %	86 %	71 %



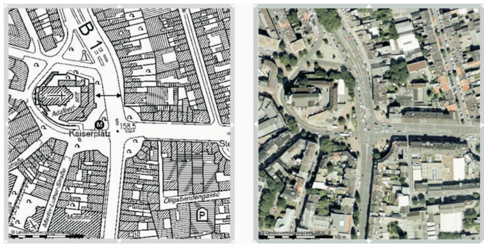
Scatter plot comparing measured (x-axis) and modelled (y-axis) annual mean values for PM10 and NO_2 (2003-2005). Dashed line indicates data-quality objectives for NO_2 as defined in Directive 1999/30/EC, Annex VIII. Annual limit value of 40 μgm^{-3} for PM10 and NO_2 is marked. Model results are displayed with an error bar of 10 % for PM10 and 20 % for NO_2.

Comparison

The presented comparison demonstrates the ability of IMMIS^{luft} to predict exceedances of and the compliance with the limit values for PM10 and NO_2 in streets. Deviations are registered for only three measurement stations in this study. It has been shown that these stations are not suitable for model verification as they do not comply with the model assumptions. Two of these cases are discussed below.

IMMIS^{luft} underpredicts

IMMIS^{luft} underpredicts the measured NO_2 values more than 30 %. The station is located near a large crossroad. The measurements are affected by emissions of the crossing roads which are not considered in the model calculations. Additionally, the chosen street section does not comply with the IMMIS^{luft} specification "length of a street section > twice the distance between the opposite buildings".



Site map and aerial view of measurement station Aachen Kaiserplatz (station location marked with M, IMMISluft-cross section marked with an arrow). Topographical map and aerial view provided by Landesvermessungsamt NRW.

IMMIS^{luft} overpredicts

The Düsseldorfer Straße in Mönchengladbach is in parts a typical street canyon with closely lined-up buildings on both sides. The measurement station is located on a grass strip with a lower building density and better ventilation. Consequently, IMMIS^{luft} overpredicts the measurements.

Site map and aerial view of measurement station Mönchengladbach Düsseldorfer Straße (station location marked with M, IMMIS^{luft}-cross section marked with an arrow). Topographical map and aerial view provided by Landesvermessungsamt NRW.

Conclusions

The screening model IMMIS^{luft} for calculating concentrations of air pollutants in inner-city roads is very well suited to identify hot spots where exceedances of limit values according to EC Directives are to be expected. This was validated in a study comparing modelled and measured values for three years at 15 measurement sites in the German federal state of North Rhine-Westphalia.

Statistical approaches to derive NO_2 from NOx and their basic assumptions were discussed. The importance of giving a prediction interval together with the results of statistical approaches was shown. Recent measurements illustrated that the increasing level of NO_2 direct emissions necessitates the improvement of the existing approaches. A first step would be to update and validate the statistical functions with data from recent years. Further improvement will arise from quantifying and parameterizing the influence of NO_2 direct emissions and implementing and considering their effects in micro-scale models.