AIR CONCENTRATIONS IN CONCRETE DAILY SITUATIONS AS A BASE OF HYGIENIC ASSESSMENT

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ABSTRACT

Official measuring points cannot represent the real burden of individuals by exhaust gases. Although quality of life in Vienna is referred as very high, the situation concerning air concentration is similar to other European cities. A sound base for an environmental hygienic evaluation has to consider different mobility patterns and different sensibility for different components of exhaust gases. In fact there is a wide range of biologic sensitivities for irritant gases like ozone or nitrogen dioxides as well as particulate matters. Among sensible groups of persons we have to classify children as well as already affected people (bronchitis, asthma). Together with the Austrian Federal Environmental Agency a pilot study was carried out (finished in December 2006) to be able to characterize the health effects on children in urban areas,. In order to define the health effects on children in urban areas, particulate matter, nitrogen oxides and carbon monoxide concentrations were measured in schools and the urban environment of children, including measures inside different modes of transport. Measurements in different transport modes as well as in street sections and within buildings (and different floors) showed a high daily background concentration as well as considerable concentration peaks depending on traffic volume. The results of the study suggest that extensive, large-scale reductions of particulate matter and its gaseous precursors are required for a decrease of the related health risks for children and other vulnerable groups.

Keywords: *Nitrogen oxides, reaction gases, daily dose rate, schools, children, activity patterns, Vienna*

1. INTRODUCTION

The general research objective was to evaluate the concrete load of persons in their daily patterns of travel behaviour.

Official measuring points do not adequately represent the exposure of individuals to exhaust gases. Former studies aiming similar objectives carried out in Vienna between 1988 and 1992 [1] in different transport modes (such as car, train, metro, tram bicycle) as well as in cross sections of streets found the highest mobility-related pollutant concentrations to be in car interiors. The average NO_2 concentrations in passenger cars exceed the half-hour threshold value of the Austrian Academy of Science. In some cases, especially on main roads, this situation was also given for the NO_2 exposure of pedestrians as well. From an environmental hygienic point of view, one of the main problems is the combination of a relatively high ambient pollutant concentration with a number of peaks exceeding short-time threshold limits.

About 15 years later, a study with a similar research question was carried out. In order to determine the concrete load of exhaust gases of traffic users as well as residents it is necessary to evaluate the dose for traffic users in their different mobility patterns. Paracelsus once stated

"Dosis sola fecit venenum" (Only the dose makes the poison). The toxic effect w, therefore is given by

$$w = c \bullet t.$$

c denotes pollutant concentration and t exposure time.

A sound basis for an environmental hygienic evaluation has to consider different mobility patterns and different sensibility for different components of exhaust gases. In fact there is a wide range of biologic sensitivities for irritant gases like ozone or nitrogen dioxides, as well as particulate matters. Among these sensible groups of persons we have to classify children as well as already affected people (bronchitis, asthma).

2. METHODS AND MEASUREMENT ACTIVITIES

A pilot study carried out in cooperation with the Austrian Federal Environmental Agency (Umweltbundesamt) tried to evaluate the situation of school children in Vienna. The study aimed at evaluating the particulate matter and pollutant concentration affecting children in their daily life. The field campaign was designed to include a school located at a road with high traffic volumes and another located at a calm side street along with other daily-life locations of children (parks, roads and buildings). The pollutants measured included particulate matter (PM10 and PM2.5), NO/NO_2 and CO. Daily activity and mobility patterns were surveyed by a questionnaire.

The measurements carried out by the Institute for Transport Planning and Traffic Engineering were organised in two field campaigns covering winter (December 2005) and late spring conditions (May–June 2006). Pollutant measurements were accompanied by measurements of control parameters such as traffic volumes, wind direction and wind speed. The time span covered by the measurements amount to over 53 hours (car interior; stored in 10 sec-intervals), 58 hours (public space sites including roadside and parks) and, finally, 124 hours (school interior).

3. MEASUREMENT RESULTS

Nitrogen dioxide and particular matters are most critical in a human hygienic point of view. For the sake of conciseness, only the results concerning NO_2 will be referred in the framework of this paper. However the development of the particulate matter is also still a problem in Vienna. So, the PM2.5 concentrations measured at both schools were comparable to those measured at monitoring stations nearby main traffic arteries and therefore considerably higher than the concentrations at typical urban background stations. No considerable differences between the measurement stations were found in the proportion of elemental and organic carbon in particulate matter.

3.1. Air Concentrations

Similar to the results from the years 1988 to 1992, the latter measurements 2006 [5] showed a great variability in air concentration. This holds true for all measured pollutants such as CO, NO, NO_2, PM2.5 and PM10. Parameters such as traffic volume and the average speed of the transport flows, together with meteorological influences (wind speed and direction), strongly influence the results obtained both in car interior and public space measurements.

Figure 1 summarizes the nitrogen dioxide immissions measured in the car interior, at public space sites (roadside and parks) and within the two schools.

Previous work [2][3] reveals the significant influence of traffic volumes, as represented by different road categories, and of effective road width between building fronts. In general, the variability of NO_2 concentrations is lower than that of NO or CO.

In schoolyards and parks regularly visited by children, concentrations (height of 1.7 meters) of all measured pollutants were lower than on streets, due to the larger distance to pollutant emitters. Average NO_2 concentrations ranged from 17 to 33 ppb.

Measurements during car rides showed that the average concentrations increased with the higher rank of the street. It was shown that concentrations on certain types of streets increase with building density. On roads with high traffic volumes, average NO_2 concentrations between 55 and 66 ppb were recorded.

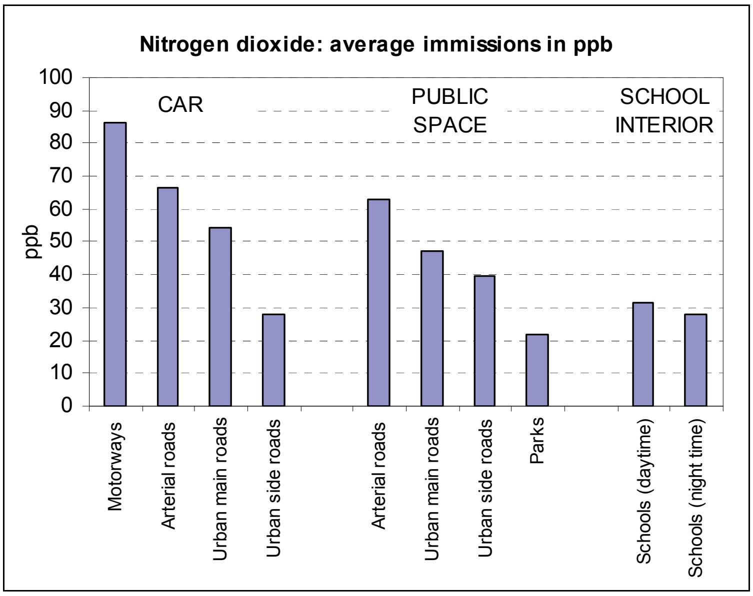

Figure 1: Variability of NO_2 concentrations (average of all measured values) in different road types and in other typical locations of children, 2006

3.2. Example of Concentrations in Schools

The development of NO_2 concentrations in the schools followed the trends in the ambient air. The average nitrogen dioxide concentration in the traffic-affected school (roughly 24 ppb over two weeks in May/June 2006) is comparable to the concentration at a traffic-affected ambient air quality monitoring station in Vienna. The average concentration at the other school (not directly affected by traffic) is comparable to the concentrations at highly affected background monitoring stations.

Additional measurements in the schools showed a decrease in pollutant concentration on higher floors, especially in the traffic-affected school (Figure 2). In this school, NO_2 concentrations increased when the windows were opened, especially in winter. This is the result of the raised background concentration of NO_2. The reason for this phenomenon is the formation of NO_2 as the result of an oxidation process, which generally leads to concentration peaks in a certain distance to the emittent.

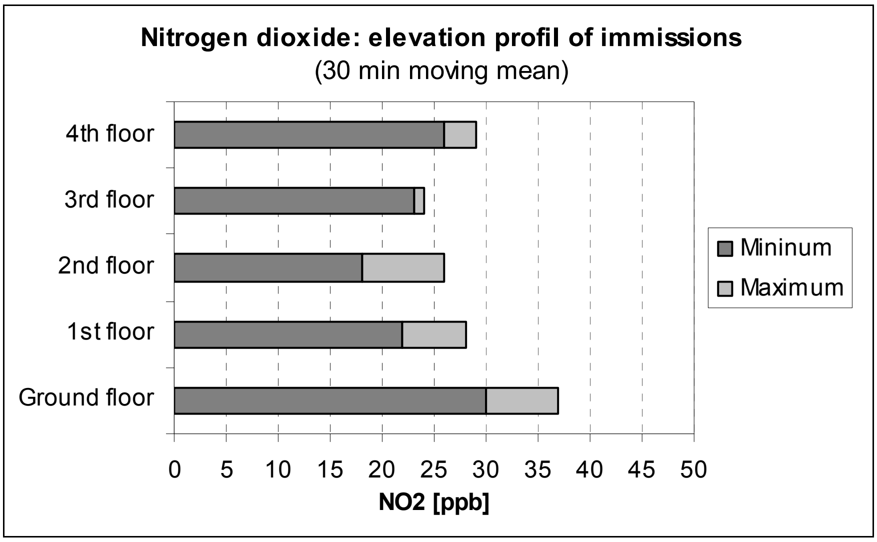

Figure 2: NO_2 concentrations on different floors of the traffic-affected school

3.3. Development of the air concentrations between 1991 and 2005

One of the objectives of current study was to compare data from different field campaigns in order to obtain information over concentration developments. It has to be noted, however, that the old and new field campaigns are not fully comparable. Due to the relatively limited number of measurements carried out in 2005/06, the data sample allowed not to calculate the significance of the parameters such as wind speed, wind direction, traffic volume, average speed and the composition of the vehicle fleet. The results presented in the following therefore only indicate rough trends.

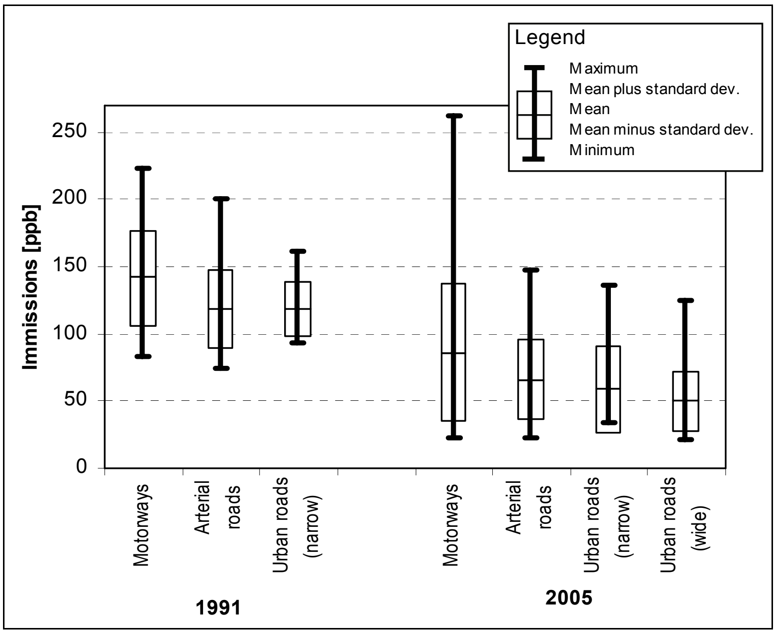

Figure 3: Comparison of NO_2 measurement results from car rides (car interior) in different road categories in the years 1991 and 2005

A comparison with information from automated measuring facilities [4] 2002 reveals that irritant gases such as NO_2 were not reduced to the expected degree. Higher traffic volumes on the transport system compensated technological improvements on the vehicle level; increased shares of goods vehicles and diesel engines likewise played a role in this outcome.

Technological progress is apparently more effective in reducing pollutant concentration in the car interior emitted by vehicle(s) directly in front (Figure 3). The mean values of NO_2 concentrations decreased more than the maximum values. The latter are results of special situations like rides directly behind lorries or busses. Measurements on the streets (measurement height of 1.7 meters) showed that the measured concentrations of all pollutants increase with the type of street and traffic volume.

The measurement results obtained on roadsides show that the peak exposures for pedestrians—as during car rides—exceed the threshold limits of the Austrian Academy of Science, which defines a half-hour threshold value of 105 pbb for NO_2. Contrary to mean immissions, peak immissions were not reduced in the course of the last 15 years (see Figure 4)

At the same time, ambient exposure—as represented by immissions in parks—has risen sharply. Increased ambient concentrations were also identified as reason for the observation that airing in many cases led to NO_2 concentration increases in classrooms. This phenomenon was limited to NO_2 immissions only.

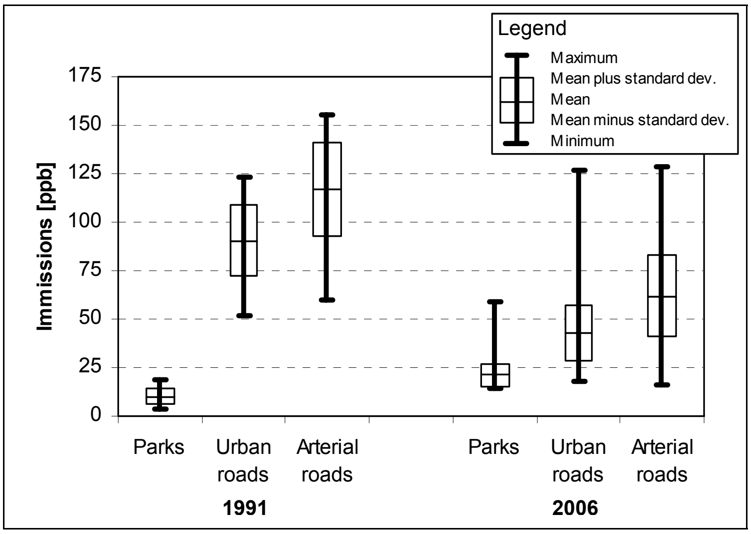

Figure 4: Comparison of average public space pollutant and car rides concentrations; results from the field campaigns 1988–1992 and 2005/2006

3.4. The daily dose

The filled-in questionnaires revealed information on the duration of the trips undertaken by children and on their average stay at school, at home and at other locations. In addition, information on the type of street where they live and on their stays outdoors was collected.

This information was combined with average pollutant concentrations in order to determine average doses for various typical daily activity patterns. In most of the cases considered, mobility (including trips by foot as well as by car) constituted the phase of highest pollutant exposure (see Figure 5).

The most influential parameter in the calculation of the overall daily dose is the children's place of residence! The exposure of the flats—clearly attributable to transport in urban areas—are a decisive parameter for the dose calculation.

Dose exposures were calculated on the basis of mobility patterns. However, a vast set of potential activity combinations can be imagined—including amongst others trips in different modes of transport, outdoor activities in parks or activities inside buildings on different floors.

The analysis revealed that the mobility-related share of dose exposure was reduced in comparison to the field campaign 1988–1992. However, mobility still constitutes the most problematic area for all considered activity and mobility pattern combinations.

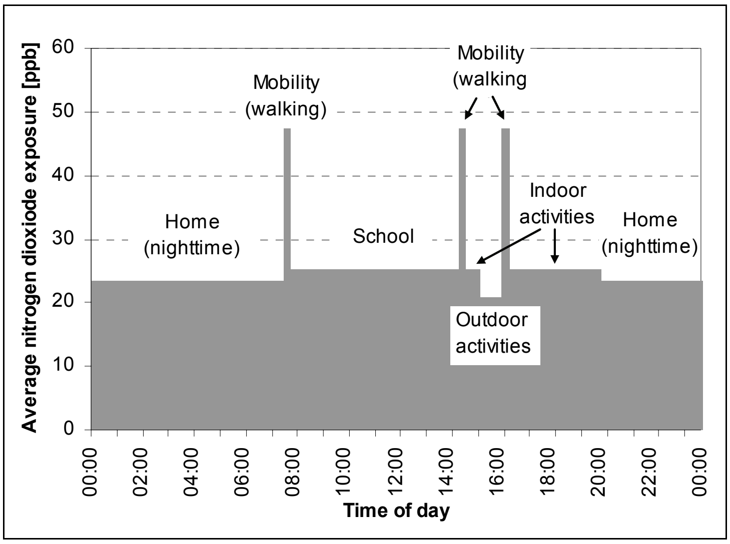

Figure 5: Average nitrogen dioxide in one of the activity patterns considered as a basis for dose calculations (low exposure school, residence in side road, mobility by foot)

The highest dose exposures originate—due to the long duration of the stay—from the time spend at home during the night. There are significant differences between flats in higher floors located in side streets and flats in lower floors located at main roads. Moreover, peak exposure remains an environmental hygienic problem, particularly for pedestrians and car drivers.

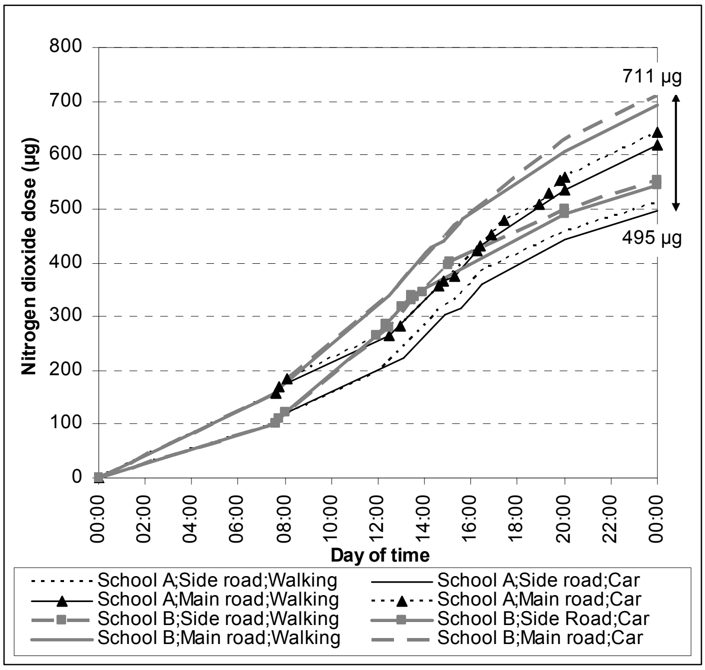

Figure 6: NO_2 dose exposure for different activity and mobility patterns of children

It was shown that the daily dose through respiration for various combinations of daily activities ranges between 500 and 700 µg of NO_2. Children living on main roads have a clear disadvantage compared to those living on side streets. Their daily NO_2 dose is higher, independent of the location of their school and the type of mobility they usually engage in.

Figure 6 shows the overall NO_2 dose inhaled within a day in various activity and mobility patterns. In the calculation, the respiratory volume of children was assumed to be 7 litres per minute. In the figure, school A and B refer to the low traffic-affected and high traffic-affected school, respectively. Side or main road characterizes the location of the place of residence and walking or car denotes the main mode of transport.

The variation of locational conditions concerning residence and school together with the modal choice for mobility results in daily dose differences of up to 30 % within the same city district of home and school location.

4. SUMMARY AND CONCLUSIONS

Overall, the pollutant measurements carried out in the present project showed a high background concentration in combination with considerable concentration peaks. Beside those results which were empirically interesting for modelling like correlations with traffic volume, street width, wind direction, wind speed, share of trucks the main problem is to a evaluate the individual burdens by exhaust gases.

To begin with, peak exposures in highly frequented roads for both pedestrians and car drivers still exceed the applicable threshold values of the Austrian Academy of Science. At the same time, ambient exposures have sharply risen. From an environmental hygienic point of view, this combination of high background concentrations together with peaks in the mobility phase (about 3% of time of day) is particularly problematic.

The calculation of dose exposures revealed another core area of environmental monitoring, namely the consideration of the domestic circumstances of different population groups. In particular, narrow urban roads have to be taken into account; reducing traffic volumes is there an urgent task. Moreover, the average NO_2 concentration in the traffic-affected school is comparable to the concentration at traffic-related monitoring stations in Vienna. This makes negative effects likely to occur.

Individual modal choice decisions in relation to children's everyday mobility do not have a major impact on their dose exposure. Nevertheless, the mode of transport chosen (e.g. for the way to school) is important from a medical point of view as it involves considerable peak concentrations.

The results of the study suggest moreover that extensive, large-scale reductions of particulate matter as well as gases investigated are required for a decrease of the related health risks for children and other vulnerable groups. For NO_2 concentrations, which showed considerably lower spatial differences, a reduction of traffic-related NOX emissions in a wide scale will be necessary for a significant reduction of the health risks.

Besides technical measures (mainly involving stricter legislation), non-technical actions can lead to distinct improvement. Traffic management may considerably reduce pollutant exposure in residential areas. Moreover, better integration of environmental and health concerns in urban planning especially under consideration of street types, wind direction and so on in relation to the traffic volume passing through the street may lead to significant improvements.

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