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# Traffic-related $NO_2$ and the prevalence of asthma and respiratory symptoms in seven year olds

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*Traffic-related $NO_2$ and the prevalence of asthma and respiratory symptoms in seven year olds. M. Studnicka, E. Hackl, J. Pischinger, C. Fangmeyer, N. Haschke, J. Kühr, R. Urbanek, M. Neumann, T. Frischer. ©ERS Journals Ltd 1997.*

**ABSTRACT: The aim of this study was to determine whether outdoor nitrogen dioxide ($NO_2$) was associated with the prevalence of asthma and respiratory symptoms.**

**In eight nonurban communities, 843 children resident for a minimum of 2 yrs were studied. Since industrial sources of air pollution were at least 20 km away from the study communities, $NO_2$ was considered to primarily indicate traffic-related air pollution. $NO_2$ was recorded at central monitors, and the 3 yr mean exposure was calculated. Asthma and respiratory symptoms were assessed according to the International Study on Asthma and Allergy in Childhood.**

**Prevalence of asthma at some time ("ever asthma") was associated with long-term $NO_2$. In parallel with increasing levels of $NO_2$ (community specific 3 yr mean 6.0–17.0 parts per billion (ppb)), asthma prevalence was 2.5, 1.4, 1.6, 2.3, 3.4, 3.6, 7.6 and 8.5%, respectively (p=0.002 for trend). The prevalence odds ratios (PORs) for "ever asthma", following adjustment for gender, age, parental education, passive smoke exposure, type of indoor heating, and parental asthma, were 1.28 (95% confidence interval (95% CI) 0.20–7.98), 2.14 (95% CI 0.40–11.3) and 5.81 (95% CI 1.27–26.5), when each of two communities with low, regular and high $NO_2$, respectively, were compared with the two communities with very low $NO_2$. For symptoms "wheeze" (adjusted PORs for increased $NO_2$: 1.47, 1.23 and 2.27) and "cough apart from colds" (adjusted PORs for increased $NO_2$: 1.49, 1.93 and 2.07), a similar trend was seen.**

**In this study a significant relationship was observed between traffic-related nitrogen dioxide and the prevalence of asthma and symptoms. Whether this association is causal has to be tested in longitudinal studies.**

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An increase in childhood asthma has been observed over the last two decades [1]. Several hypotheses have been advanced to explain this increase. Automobile exhaust-related air pollution has been found to be associated with respiratory symptoms [2], and an increased allergic potency of airborne pollens following surface interaction with pollutants has been discussed [3]. The diagnosis of bronchial asthma still lacks an accepted standard test to assess the presence of disease accurately. Therefore, standardized questionnaires have been developed for epidemiological studies [4]. For a population-based study, the prevalence of asthma and respiratory symptoms and the relationship with 3 yr outdoor pollution (nitrogen dioxide ($NO_2$), sulphur dioxide ($SO_2$), ozone) was investigated.

## Methods

The study was approved by the Ethics Committee of the Medical Faculty of Vienna University. The cross-sectional data presented here were recorded during the first survey of this 4 yr investigation. In Lower Austria, one of the provinces in the eastern part of the country, eight communities were selected to represent a broad range of outdoor pollution, but also to be comparable with regard to other characteristics (*e.g.* altitude, population size and socioeconomic status) (table 1). Communities with a major local source of industrial emission, or downwind or in the vicinity of such a source, were excluded *a priori*. At each community, a fixed, central monitor provided half hourly means for $NO_2$, ozone and $SO_2$. Long-term exposure was estimated as the mean of measurements recorded between January 1991 and December 1993. This interval was chosen because only from 1991 onwards were all communities equipped with monitors for $NO_2$, ozone, and $SO_2$. $NO_2$ was measured using nitric oxide ($NO/NO_x$) analysers (Monitor Labs 8840; San Diego, CA, USA). All instruments were in accordance with established standards, *e.g.* multiple point calibration of $NO_2$ monitors was performed every 6 months with an external NO gas test mixture.

In spring 1994, questionnaires were distributed to parents of children in their first or second year at primary school. In seven communities, all local primary schools

Table 1. – Population characteristics by community (n=843)

| Characteristics | Wies. | Heid. | Stix. | Mistel. | Gäns. | Krems | St Val. | Amst. |
|---|---|---|---|---|---|---|---|---|
| $NO_2$ Jan 1991–Dec 1993 ppb | 6.0 | 7.0 | 8.0 | 8.7 | 11.7 | 13.3 | 14.7 | 17.0 |
| Ozone Jan 1991–Dec 1993 ppb | 38.0 | 26.6 | 30.0 | 24.3 | 23.3 | 16.0 | 20.5 | 17.3 |
| $SO_2$ Jan 1991–Dec 1993 ppb | 8.0 | 10.7 | 8.8 | 12.0 | 12.0 | 6.0 | 6.5 | 7.2 |
| Traffic-related diesel tonnes·site$^{-1}$·yr$^{-1}$# | 0.012 | 0.038 | 0.089 | 0.14 | 0.075 | 0.29 | 0.26 | 0.25 |
| Traffic-related tyre dust tonnes·site$^{-1}$yr$^{-1}$# | 0.5 | 1.8 | 4.1 | 6.2 | 2.7 | 10.6 | 9.5 | 10.7 |
| Altitude m above sea level | 695 | 560 | 157 | 228 | 167 | 202 | 264 | 275 |
| Population size n | 4776 | 4849 | 7259 | 10234 | 6509 | 22766 | 8791 | 21972 |
| Participation % | 90 | 77 | 75 | 80 | 76 | 82 | 82 | 73 |
| Male gender % | 53 | 46 | 44 | 53 | 53 | 54 | 47 | 56 |
| Age yrs‡ | 7.7 (0.7) | 7.8 (0.7) | 7.7 (0.7) | 7.8 (0.6) | 7.8 (0.7) | 7.8 (0.6) | 7.9 (0.7) | 7.8 (0.7) |
| Parental education >8 yrs % | 33 | 19 | 35 | 36 | 49 | 41 | 34 | 31 |
| Passive smoke exposure % | 19 | 31 | 43 | 27 | 41 | 45 | 31 | 41 |
| Parental asthma % | 2 | 3 | 6 | 2 | 7 | 9 | 8 | 5 |
| Perception of traffic exhaust as heavy % | 2 | 6 | 13 | 8 | 9 | 20 | 12 | 23 |
| Single room heating by wood or coal % | 34 | 29 | 14 | 23 | 10 | 15 | 14 | 16 |
| Wheeze last 12 months % | 6 | 11 | 9 | 7 | 3 | 9 | 12 | 10 |
| Shortness of breath last 12 months % | 3 | 4 | 3 | 4 | 1 | 5 | 6 | 8 |
| Cough apart from colds last 12 months % | 4 | 9 | 11 | 7 | 10 | 12 | 12 | 13 |
| Cough at night last 12 months % | 15 | 21 | 28 | 17 | 18 | 23 | 19 | 18 |
| Cough after exercise last 12 months % | 7 | 18 | 19 | 10 | 17 | 13 | 17 | 18 |
| Hayfever last 12 months % | 0.8 | 4.3 | 1.6 | 1.5 | 1.1 | 4.3 | 1.9 | 4.2 |
| Bronchitis last 12 months % | 3 | 8 | 8 | 10 | 3 | 15 | 9 | 5 |
| Bronchial asthma last 12 months % | 3.5 | 1.5 | 1.6 | 2.3 | 0.0 | 3.7 | 5.9 | 13.3 |
| Parent-reported "ever asthma" % | 2.5 | 1.4 | 1.6 | 2.3 | 3.4 | 3.6 | 7.6 | 8.5 |

#: based on 1989 survey of traffic density [5]; ‡: mean and SD in parenthesis. Wies.: Wiesmath; Heid.: Heidenreichstein; Stix.: Stixneusiedl; Mistel.: Mistelbach; Gäns.: Gänserndorf; St Val.: St Valentin; Amst.: Amstetten.

participated, whilst in Krems only three out of six schools were contacted. The self-administered questionnaire comprised standardized items. For the assessment of "ever asthma" and respiratory symptoms, the questions from the International Study on Asthma and Allergy in Childhood (ISAAC) were used [4]. The presence of wheeze, shortness of breath, cough apart from colds, cough at night, and cough after exercise were assessed. To investigate a last 12 months doctor's diagnosis of hayfever, bronchitis, and bronchial asthma, questions from a previous study in Southern Germany were employed [6].

Parental asthma was defined as a diagnosis of asthma established in a child's mother or father. To assess socioeconomic status, years of education completed by either parent were recorded. A child's exposure to environmental tobacco smoke (absent, present) was assessed, and parent's subjective perception of traffic-related exhaust (absent, present, or heavy) at the place where the child lived was also evaluated. Whenever indoor room heating was reported, it was determined whether this involved burning of wood or coal, gas, oil, or electricity.

The relationship between $NO_2$ and respiratory disease was investigated with logistic regression analysis (table 2). Adjusted prevalence odds ratios (PORs) were derived, comparing each of two communities with regard to long-term $NO_2$ (very low: $NO_2$ 6.0 and 7.0 parts per billion (ppb); low: $NO_2$ 8.0 and 8.7 ppb; regular: $NO_2$ 11.7 and 13.3 ppb); and high: $NO_2$ 14.7 and 17.0 ppb), ozone and $SO_2$ (table 2). A Chi-squared test for trend statistic was calculated for the frequency of disease in relation to increasing levels of chronic pollutant exposure. To assess whether ambient $NO_2$ was in parallel with traffic density, estimates of a community's burden of diesel exhaust and tyre dust, based on traffic counts performed in 1989 [5], were also evaluated.

## Results

Altogether, 1,224 children were contacted and 972 (79%) agreed to participate. The main reason for nonparticipation was the longitudinal nature at the planned study, involving repeated testing of the child. Among nonparticipants, the prevalence of asthma (2.6%) was

Table 2. – Adjusted prevalence odds ratios for asthma, symptoms and air pollutants (very low *vs* low, regular and high exposure) (n=843)

| | $NO_2$§ | | | Ozone§ | | | $SO_2$§ | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low | Regular | High | Low | Regular | High | Low | Regular | High |
| Wheeze last 12 months | 1.47 | 1.23 | 2.27 | 0.66 | 0.69 | 0.49 | 0.68 | 0.88 | 0.42 |
| Cough apart from colds last 12 months | 1.49 | 1.93 | 2.07 | 1.00 | 0.58 | 0.68 | 0.75 | 0.85 | 0.72 |
| Bronchitis last 12 months | 3.09* | 3.79* | 1.94 | 0.49 | 0.85 | 0.28* | 0.21* | 0.45 | 0.56 |
| Bronchial asthma last 12 months | 1.70 | 1.47 | 8.78* | 0.32* | 0.17* | 0.20* | 2.35* | 0.22 | 0.33 |
| Parent-reported "ever asthma" | 1.28 | 2.14 | 5.81* | 0.86 | 0.20* | 0.35 | 1.70 | 0.23 | 0.67 |

§: all models are adjusted for gender, age, passive smoke exposure, parental education, parental asthma, and indoor heating with wood, coal, oil or gas. Prevalence odds ratios are calculated for the two sites with very low exposure as the reference. *: significant at $p<0.05$.

lower than among participants (4.7%). For the present analysis, 129 children who changed their place of living within the last 2 yrs were excluded. The final sample analysed at each site varied between 64 children at Stixneusiedl and 140 children at Krems.

The prevalence of respiratory symptoms and physician's diagnoses of respiratory disease were found to be increased in communities with higher $NO_2$. Prevalence of a child's "ever asthma" was 7.6 and 8.5% for communities with 3 yrs $NO_2$ >14 ppb, but was only 2.5, 1.4, 1.6 and 2.3% for communities with $NO_2$ <9.0 ppb (table 1). For a child's "ever asthma", the POR comparing three categories of increased $NO_2$ *versus* $NO_2$ ≤7.0 ppb was found to be 1.28, 2.14 and 5.81 (table 2). For a diagnosis of asthma during the last 12 months, a similar trend was observed. Symptoms "wheeze" and "cough apart from colds" were similarly associated with long-term $NO_2$, although PORs did not reach statistical significance. For ozone, significant negative associations were seen for "ever asthma" as well as a last 12 month's diagnosis of asthma, whilst for $SO_2$ spuriously significant and contradictory associations were observed for bronchitis and bronchial asthma during the last 12 months (table 2). A community's burden of diesel exhaust and tyre dust due to abrasion, estimated from traffic counts in 1989, was also found to be associated with "ever asthma". The adjusted POR for comparison of four different exposure categories (very low *versus* low, regular and high) were 2.1, 4.2. and 2.8, respectively, for diesel exhaust, and 1.3, 1.3. and 1.9, respectively, for tyre dust.

## Discussion

We report a relationship between long-term, traffic-related $NO_2$ and the prevalence of asthma and respiratory symptoms. This trend was most pronounced for lifetime asthma, assessed according to the International Study on Asthma and Allergy in Childhood (ISAAC). Taking into account a child's gender and age, parental education, parental asthma, passive smoke exposure and the type of indoor heating, this relationship remained stable. However, given that the present study focused on outdoor pollutants, no information on indoor exposure, such as allergens, pets or gas cooking, was available. This somewhat limited the validity of our observation.

For outdoor $NO_2$ and respiratory disease, most published studies have been conducted in Europe. SCHWARTZ *et al.* [7] noted that, in small children, a 20 ppb increase in daily $NO_2$ was associated with a 28% rise in cases of croup. BRAUN-FAHRLÄNDER *et al.* [8] reported that, in preschool children, outdoor $NO_2$ at levels 12–25 ppb prolonged the duration of respiratory symptoms; however, the incidence of symptoms was not increased. The limited evidence on outdoor $NO_2$ has been summarized by an expert panel, and a 15 ppb long-term exposure difference was thought to be associated with a 20% increase in the rate of childhood respiratory illness [9]. More recently, the number of asthma attacks in adults living in Helsinki (at 3 yr mean $NO_2$ of ~19 ppb) [10], the frequency of wheezing bronchitis in children in Stockholm (at 6 month mean $NO_2$ of ~20 ppb) [11], and the frequency of respiratory symptoms in Swiss children (at annual $NO_2$ of 6.6–27.7 ppb) was found to be associated with this pollutant [12].

When the least and the most exposed communities were compared, BRAUN-FAHRLÄNDER *et al.* [12] reported a POR of 1.99 for $NO_2$ and "dry cough apart from colds". This estimate was in close agreement with the present estimate for the same symptom (POR 2.07) and a similar level of exposure. However, although the same ISAAC question for "ever asthma" was used in both studies, no relationship with $NO_2$ was seen in the Swiss children. This discrepancy could be attributed to the greater age range, the greater difference in climate and urbanization, or the use of three languages in the Swiss population.

For the present data, $NO_2$ was also found in accordance with estimates of traffic-related pollutants. Diesel exhaust [13] and latex particles [14] from tyre dust have both been implicated in the enhancement of respiratory tract immunoglobulin E production. On the other hand, human experimental exposure to $NO_2$ at 100 ppb has recently been demonstrated to increase allergen responsiveness [15].

These experimental findings on the respiratory effects of traffic-related pollutants are supported by epidemiological studies of traffic density. An association has been reported between asthma symptoms, the number of vehicles counted per area, and the distance of a person's residence from busy roads. In Birmingham, UK, EDWARDS *et al.* [16] observed that a child's admission with asthma was 50% more likely when the child's residence was in an area of high traffic flow. For 4,678 children examined in Munich by WJST *et al.* [2], a child's lifetime tendency for recurrent wheezing increased in parallel with the number of cars passing through the school district daily. OOSTERLEE *et al.* [17] similarly observed that children living along busy roads reported more wheeze and a greater use of respiratory medication. However, these studies might all have underestimated the true effect of traffic pollution on asthma symptoms, because of exposure misclassification resulting from the closeness of exposed and unexposed study areas. These data on traffic density and increased symptoms would, nevertheless, be compatible with the hypothesis that $NO_2$ was an indicator variable for traffic pollution.

The influence of ozone and $SO_2$ was also assessed. A significant negative association was seen for 3 yr ozone, suggesting that ozone might protect against bronchitis and asthma. However, this observation probably resulted from the close, inverse relationship between ozone and $NO_2$, rather than indicating a biologically plausible effect. With regard to respirable particles, assessment of this pollutant is not mandatory in Austria, and therefore no data were available. Other investigators have reported a close correlation (r=0.94) between long-term exposure to particles and $NO_2$ [12]. However, for the present data the source of particulate exposure was also most likely to have been automobile exhaust.

Due to the inherent relationship between short- and long-term pollutant exposure, we cannot exclude the possibility that the association observed was partly due to a short-term effect. Given the difference observed for maximum 30 min $NO_2$ during the 3 yrs of measurement (maximum 30 min $NO_2$ in Amstetten 102 *versus* 35 ppb

in Wiesmath), such an acute effect seemed unlikely. On the other hand, a 15 ppb difference in last 24 h $NO_2$, monitored with personal samplers, has recently been related to a 10 fold increase in asthma cases [18].

Another possible bias could have been related to the use of a questionnaire. Although standardized items were used, we are well aware that this provided only an imperfect measure of asthma. However, to bias our findings any under- or over-reporting of asthma should have been in parallel with $NO_2$ exposure. The eight communities were selected to represent a homogenous study population; however, a differential access to healthcare facilities cannot be completely excluded. The frequency of other diseases, *i.e.* parental asthma or a child's hayfever, did not show the same trend with 3 yr mean $NO_2$. Moreover, inclusion of a child's hayfever as a possible confounding variable was not found to change the relationship between $NO_2$ and asthma (data not shown). Furthermore, variables possibly associated with a differential perception of a child's asthma, such as the parents' perception of traffic exhaust, were also taken into account as confounders. Following adjustment for traffic perception, the PORs for categories of increased $NO_2$ and "ever asthma" were found to be very similar: 1.71, 1.48 and 2.56. This finding also argues against a differential healthcare access in parallel with $NO_2$. Prevalence of "ever asthma" was 1.4–8.5%, estimates consistent with European data [4].

For concurrent indoor exposure, only room heating (with wood, coal, gas or oil) and passive smoke exposure were taken into account as confounding variables. However, home dampness or pets were not investigated. Childhood asthma has consistently been linked with chronic indoor allergen exposure, but the focus of our investigation was on outdoor pollutants. Whether indoor allergen exposure might have been partly responsible for the observed association with $NO_2$ remains to be determined. It could have been the case that poor housing was present more frequently in areas with heavier traffic-related $NO_2$ exposure.

In summary, a close association was observed between traffic-related nitrogen dioxide, respiratory symptoms and asthma in 7 yr olds. Given that this analysis was not the primary aim of the present study, it has to be regarded a hypothesis-generating result. Furthermore, due to the cross-sectional nature of the data, we cannot decide whether this indicator pollutant was related to the duration of symptoms or to the new occurrence of disease.

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