

Air pollution and upper respiratory symptoms in children from East Germany

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Air pollution and upper respiratory symptoms in children from East Germany. E. von Mutius, D.L. Sherrill, C. Fritsch, F.D. Martinez, M.D. Lebowitz. ©ERS Journals Ltd 1995.

ABSTRACT: Whereas evidence of adverse effects of air pollution on lower respiratory tract illnesses in children is increasing, little is known about the effects of high and moderate levels of air pollution on the incidence of upper respiratory illnesses.

9 to 11 year old schoolchildren (n=1,854) living in Leipzig, East Germany were studied. The presence of upper respiratory symptoms was documented by a physician. Daily mean and maximum concentrations of SO₂, particulate matter (PM) and NO_x, as well as temperature and humidity, were measured. Furthermore, a self-administered questionnaire was distributed to the parents to assess confounding factors.

Parents of 1,500 (81%) children returned the questionnaire. When controlling for paternal education, passive smoke exposure, number of siblings, temperature and humidity, increased risks for the development of upper respiratory symptoms were found in the winter months for SO₂ mean concentrations (odds ratio (OR)=1.72; 95% confidence interval (95% CI) 1.19–2.49), NO_x mean concentrations (OR=1.53; 95% CI 1.01–2.31) and PM maximum values (OR=1.62; 95% CI 1.08–2.45). In the summer months, only NO_x mean concentrations were associated with a significantly increased risk (OR=1.82; 95% CI 1.21–2.73). A combination of high mean levels of different pollutants resulted in the highest risk (OR=2.10; 95% CI 1.30–3.37 in the winter, and OR=2.16; 95% CI 1.23–3.81 in the summer).

We conclude that high concentrations of SO₂, and moderate levels of particulate matters and NO_x are associated with an increased risk of developing upper respiratory symptoms in childhood. The highest risk was found when the concentrations of all three pollutants ranged in their upper quartiles.

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Environmental exposure to high levels of air pollution, such as ambient sulphur dioxide (SO₂), nitrogen dioxide (NO₂) and particulate matters (PM) has long been related to the incidence of lower respiratory tract illnesses in children [1–6]. We previously reported an increased prevalence of bronchitis and cough in 9–11 year old children living in Leipzig, a highly polluted city in East Germany, when compared to Munich, a less polluted city in West Germany [7, 8]. Air pollution in Leipzig was characterized by very high levels of SO₂ and PMs.

Information about the effects of air pollution on the development of infectious respiratory diseases in children, however, is scanty. BRAUN-FAHRLÄNDER *et al.* [9] reported a correlation of total suspended particulates (TSP) and NO₂ with the incidence and duration of upper respiratory symptom episodes in preschool children. Others found a correlation between these two pollutants and croup in children of the same age group [10]. Furthermore, a significant association between the prevalence of upper respiratory infections and residence in a Finnish community that was moderately polluted by

SO₂ has been reported [11]. From these previous reports, it remained unclear whether the underlying relationship followed a continuous dose response pattern or whether a certain threshold level had to be exceeded for the manifestation of disease.

The aim of the present report was to investigate the importance of high and moderate levels of air pollution on the incidence of upper respiratory symptoms in 9–11 year old children living in Leipzig, East Germany. Air pollution was assessed by daily measurements of mean and maximum levels of SO₂, NO_x and PMs. The incidence of upper respiratory symptoms was mainly recorded during examination of the children.

Methods

Study area

Leipzig is a city with heavy air pollution caused by private coal burning and industrial emissions. Average

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monthly and annual concentrations of SO₂, particulate matters, NO₂ and ozone have been reported previously [7]. Leipzig has approximately 535,000 inhabitants and is located in the north western part of Saxony, East Germany.

Study population

Study participants included all fourth grade students (n=1,854) from a random sample of 39 schools in Leipzig, Germany. The parents of each child received a self-administered questionnaire through the schools, that was developed according to international recommendations [12] and included questions concerning sociodemographic characteristics, doctors' diagnoses of respiratory and allergic disorders, number of siblings, current parental smoking habits and type of heating.

Parents were, furthermore, asked to give their written informed consent for participation of their children in lung function testing. These measurements were then performed once in each child in random order at the respective school. At this time, the physician supervising the field work examined the children and recorded if a child had upper respiratory symptoms, such as running nose, cough or hoarseness. In addition, information was obtained from the child, by asking, "Do you have a cold?" Subjects were classified as currently having an upper respiratory illness if symptoms were observed by the physician or the children gave a positive response to the question. A median of 15 subjects (range 6–29 subjects) was studied per day. On two days in winter and summer, the number of subjects fell below six. On each of those four days, four children were examined.

The sampling survey with administration of questionnaires and physical examination of study subjects was carried out from October 1991 until July 1992. All study methods had been approved by the Ethics Committee of the University of Leipzig.

Air pollution

Information about air pollution and atmospheric conditions was obtained from the Landesuntersuchungsanstalt für das Gesundheits- und Veterinärwesen Sachsen, a local air pollution agency. Daily assessments of mean and maximum air pollution concentrations, temperature and humidity were available from air monitoring stations next to the respective schools. The air pollution measurement techniques were chemiluminescence for NO_x, beta-absorption for PMs, and ultra violet (UV) fluorescence for SO₂ [7]. Air pollution concentrations were divided into high and low seasonal periods based on daily mean values. October to March was considered the high concentration period and April to July the low concentration period. Air pollution data within each seasonal period were then categorized into quartiles. Evaluations of the effect of high air pollution on the prevalence of colds were made between the upper and lower three

quartiles for each pollutant separately. Additional analyses examined the same relationship but between days when all three pollutants ranged in the upper quartiles, and days when no pollutant reached high concentrations. In addition, possible effects of previous day exposure were investigated.

Statistical methods

Cases were used to calculate daily prevalence rates in the limited number of children undergoing pulmonary function testing each day. Kendal's Tau (one-sided) was calculated to estimate the significance of the increase in the prevalence rates with increasing air pollution levels. The association between upper respiratory symptoms and the level of air pollution was furthermore examined using logistic regression models. This approach yields odds ratios which are adjusted for possible confounding variables. In this analysis, we considered exposure to parental environmental tobacco smoke (ETS), socioeconomic status (SES), number of siblings, temperature and humidity, as possible confounders. In addition, the type of heating as an estimate for indoor pollution was entered into all models. Seasonal differences were accounted for by stratification of two concentration periods. Father's education, used as a surrogate for SES, and ETS were transformed into dichotomous variables, with cut-off values of >12 yrs of schooling and mother smoking or any other person reporting to smoke more than 20 cigarettes·day⁻¹, respectively. The number of siblings was entered into the logistic model as a discrete variable (range 0–10). Finally, the type of heating was included as a binary variable, selecting households using gas, fuel or wood as indoor heating source and referencing them to households with central heating.

Results

The questionnaire was distributed to 1,854 children in Leipzig. Parents of 1,500 (81%) children, 786 girls and 714 boys, returned the questionnaire. Of the eligible children for whom the questionnaire was returned, 9% did not undergo physical examination. The prevalences of current asthma, recurrent bronchitis and hay fever

Table 1. – Descriptive statistics

	Males (n=708)	Females (n=784)
Continuous variables*		
Age yrs	10.3±0.02	10.3±0.02
Height cm	143±0.3	143±0.3
Weight kg	35.2±0.3	35.6±0.3
Dichotomous variables†		
Paternal education >12 yrs	28	26
Passive smoke exposure	31	31
Number of siblings ≥2	22	22

*: values are mean±SEM; †: values are percentages.

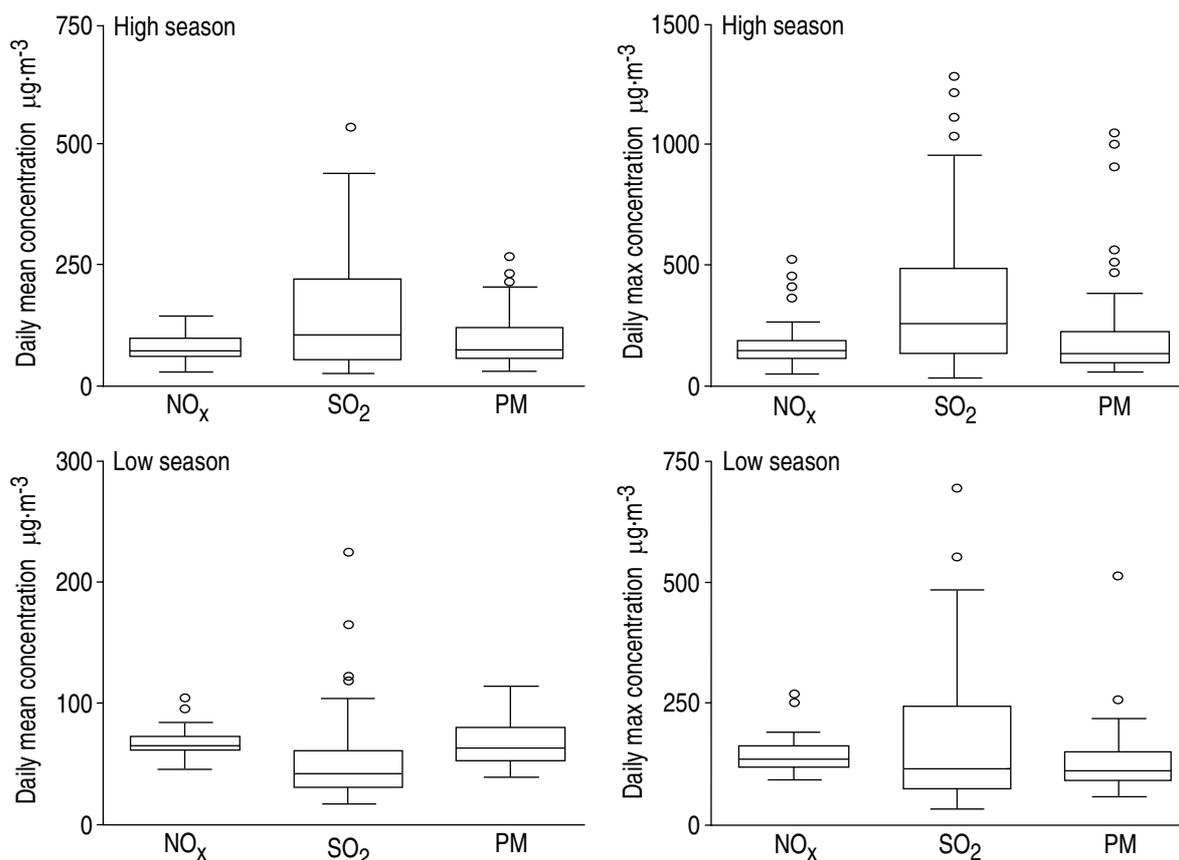


Fig. 1. — Concentrations of NO_x , SO_2 and PM during high and low pollution periods, given as boxplots. The lower boundary of the box is the 25th percentile, the upper boundary is the 75th percentile. The line in the box represents the median. The bars show the 5th and 95th percentiles, respectively, and the circles outliers. Air pollution levels were divided into high and low seasonal periods based on daily mean values. October 1991 to March 1992 was considered the high concentration period and April 1992 to July 1992 the low concentration period. PM: particulate matter.

were not increased among nonattending subjects when compared to participating subjects. Descriptive statistics, means and prevalence rates, are given in table 1. There were no statistically significant differences between genders in any of these measures. Approximately 27% of children had fathers who had completed more than 12 yrs of schooling and 31% were exposed to maternal or other heavy smoking. Twenty two percent of the children had at least two siblings and 7% had three or more siblings. In 93% of children with upper respiratory illnesses, typical symptoms such as running nose, cough or hoarseness were documented by the physician. The remaining 7% of children reported having a current cold, but did not show upper respiratory symptoms at physical examination.

Air pollution characteristics are given in figure 1. During the winter months, the concentrations of SO_2 and PMs increased considerably due to private coal burning for heating. SO_2 daily maximum concentrations ranged 40–1,283 $\mu\text{g}\cdot\text{m}^{-3}$, and daily maximum concentrations of PMs reached 53–1040 $\mu\text{g}\cdot\text{m}^{-3}$. These levels dropped substantially during the summer months, when pollution was mostly due to industrial emissions. Within the high pollution period, the European Standards [13] for SO_2 were exceeded on 52% of test days, on 51% of test days for NO_x and on 28% of test days for PMs. NO_x levels did not follow a strong seasonal pattern, and

concentrations in the winter months only slightly exceeded concentrations in the summer months. NO_x maximum concentrations ranged 49–502 $\mu\text{g}\cdot\text{m}^{-3}$ in the high pollution season and 89–261 $\mu\text{g}\cdot\text{m}^{-3}$ in the low concentration period. The European Standards for NO_x were exceeded on 14% of test days in the low pollution period.

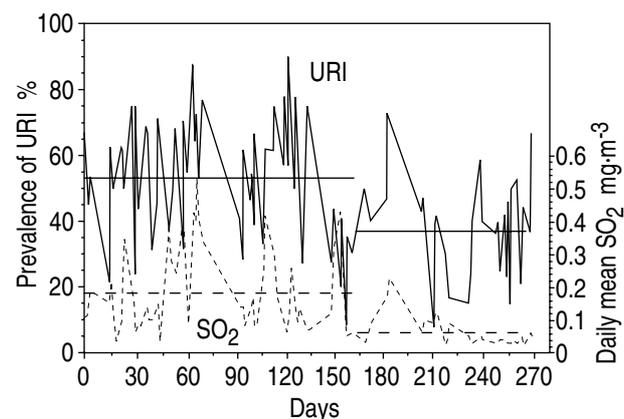


Fig. 2. — The daily prevalence of upper respiratory illnesses (URI) is given with the daily mean concentration of SO_2 over the study period October 1991 to July 1992 in Leipzig, East Germany. The horizontal bold line represents the mean prevalence of upper respiratory illnesses for the high and low concentration periods. The horizontal dashed line indicates the mean concentration of SO_2 for the high and low concentration periods.

Figure 2 illustrates the daily prevalence of upper respiratory illnesses and daily mean concentrations of SO_2 . During the high pollution period the mean prevalence of upper respiratory illnesses was 53% and the mean concentration of SO_2 was $188 \mu\text{g}\cdot\text{m}^{-3}$. These means dropped considerably during the low pollution period to 37% and $57 \mu\text{g}\cdot\text{m}^{-3}$, respectively.

The prevalence rates of upper respiratory illnesses by quartiles of air pollutant concentrations during the high concentration period are given in figure 3. All air pollutants had linear trends, with prevalence rates rising with increasing concentrations, but these trends were only statistically significant for NO_x and PMs in the daily mean measures and for PMs in the daily maximum measures. When combinations of daily mean concentrations of pollutants were considered, the prevalence of upper respiratory illnesses in the high pollution period increased from 43% on days when no pollutant ranged in the upper quartile to 59% when all three pollutants were in their upper quartile ($p < 0.05$).

The results of the logistic regression analyses are shown in table 2. All models controlled for paternal education, passive smoke exposure, the number of siblings, temperature and humidity. Single pollutant models, including

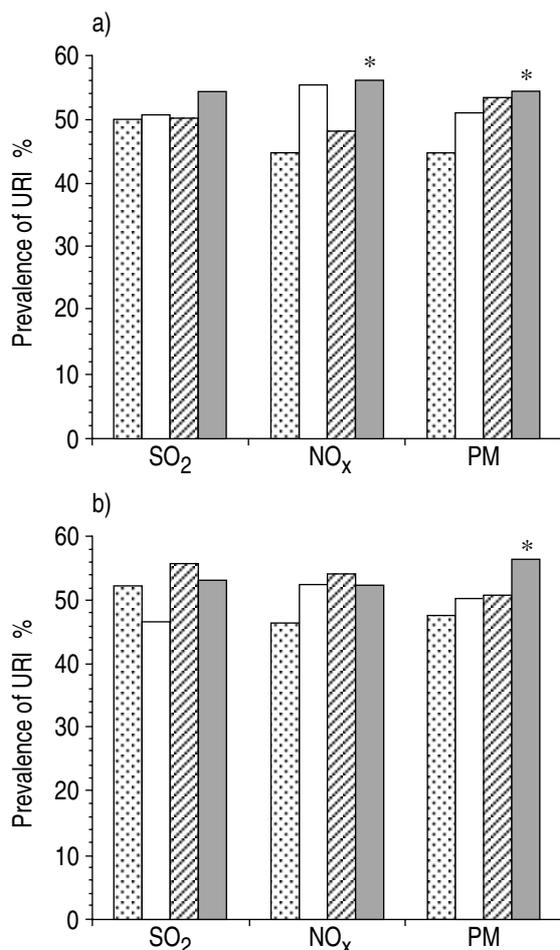


Fig. 3. – Prevalence rates of upper respiratory illnesses (URI) by quartiles of: a) daily mean; and b) daily maximum air pollutant concentrations during the high concentration period. □: 1 quartile; ◻: 2 quartile; ◻: 3 quartile; ◻: 4 quartile. PM: particulate matter. *: $p < 0.05$, Kendall's Tau.

Table 2. – Odds ratios from logistic regression analysis

Period		Daily mean		Daily maximum	
		OR	95% CI	OR	95% CI
High	NO_x	1.53*	1.01–2.31	1.51	0.94–2.41
	PM	1.28	0.83–1.99	1.62*	1.08–2.45
	SO_2	1.72*	1.19–2.49	1.26	0.80–1.96
	Combination	2.10*	1.30–3.37	1.91*	1.01–3.63
Low	NO_x	1.82*	1.21–2.73	1.26	0.85–1.86
	PM	1.00	0.66–1.50	1.13	0.75–1.70
	SO_2	1.40	0.95–2.07	0.99	0.66–1.47
	Combination	2.16*	1.23–3.81	1.72	0.77–3.86

*: $p < 0.05$. OR: odds ratios; 95% CI: 95% confidence interval; PM: particulate matter. Additional significant factors in the logistic regression model included paternal education, passive smoke exposure, the number of siblings, temperature and humidity.

NO_x , SO_2 and PMs, respectively, were all associated with a significantly increased risk of developing upper respiratory illnesses during the high concentration period. The associations of SO_2 and NO_x reached statistical significance only for daily mean values. In contrast, only daily maximum levels of PMs were significantly related to an increased risk in high pollution period. In the low concentration period, only NO_x daily mean values were significantly associated with an increased risk. In two pollutant models including SO_2 and PMs, the relations observed in single pollutant models did not change significantly. When all three pollutants were in their upper quartile, the risk increased significantly during the high concentration period both for daily mean and daily maximum concentrations. In the low pollution period, only the combination of daily mean values was associated with an increased risk of developing upper respiratory illnesses. When additionally controlling these models for current asthma and skintest reactivity, and for the type of heating as an estimate for indoor pollution, the associations reported herein did not change significantly.

We furthermore investigated the relationship between air pollution concentrations from the previous day and the prevalence of upper respiratory illnesses (data not shown). There was no one-day lag effect for NO_x and PMs, but there was for the effects of daily mean SO_2 on the prevalence of upper respiratory illnesses.

Discussion

The results of this study suggest that high concentrations of SO_2 , and moderate levels of particulate matters and NO_x are associated with an increased risk of developing upper respiratory illnesses in schoolchildren. After controlling for paternal education, passive smoke exposure, the number of siblings, the type of heating, temperature and humidity, high mean concentrations of SO_2 and NO_x were significantly related to an increased risk of having upper respiratory symptoms at the time of examination. The association between upper respiratory

illnesses and particulate matters, however, was only seen with high maximum concentrations. A combination of high levels of different pollutants resulted in the highest risk.

Some methodological limitations in our study need to be addressed before interpreting the results. The survey in Leipzig was not designed as a longitudinal study but as a prevalence survey on asthma and allergic disorders in East Germany [8]. Therefore, prevalence rates in a limited number of children undergoing pulmonary function tests each day rather than incidence rates were calculated. However, it is unlikely that the study design had a major influence on the results reported. The physician examining the child was not aware of any interest in the relationship between air pollution and upper respiratory symptoms. Nevertheless, we cannot completely rule out the possibility that very high levels of air pollution perceptible as a pungent odour, might have led to over-reporting of symptoms by the physician. We do not have any information on those children not attending school. Preferential selection of those subjects fit enough to attend may have biased our estimates towards null.

The symptoms evaluated in the children at the time of testing were typical symptoms of upper respiratory tract infections, such as running nose, cough or hoarseness. These symptoms, however, are nonspecific and may be attributed to a variety of causes. Since no further aetiological investigations, such as blood tests or throat swabs, were performed, we cannot definitely separate infectious from irritative, allergic or other causes. However, asthma and atopic sensitization in the child, as assessed by reported physician's diagnoses and skin-prick tests, respectively, did not explain our findings when additionally including these variables into the different models.

Significant associations between SO_2 , PM and the prevalence of upper respiratory illnesses were only found during the high pollution period. Mean concentrations, but not maximum levels, of SO_2 were associated with a significant risk for developing symptoms of the upper respiratory tract. Conversely, only maximum values of PM, but not mean levels, showed an increased risk in the children. These findings suggest that high continuous exposure rather than peak levels of SO_2 may increase the prevalence of upper respiratory illnesses, whereas PMs may exert their adverse effects mainly through peak exposures. The results of the previous day analyses support these hypotheses. The increased risk associated with high maximum concentrations of PM disappeared, whereas previous day mean concentrations of SO_2 were still significantly associated with the occurrence of upper respiratory symptoms in the child. No threshold level could be identified. All associations showed rather a continuous dose response pattern.

Particulate air pollution has been associated with increased prevalences of bronchitis and cough in childhood [4, 7, 8, 14]. Moreover, increases in reported incidence of respiratory symptoms in asthmatic and asymptomatic schoolchildren [4], as well as in healthy preschool children [9], have been reported. Furthermore, particulate air pollution has been related to increased mortality from

all causes in adults [15]. Since only very small particles can be inhaled into the lungs, the focus of these studies has predominantly been on particles with an aerodynamic diameter of less than $10\ \mu\text{m}$ (PM₁₀). Most of these associations were found for concentrations of TSP, PM₁₀ and PM with aerodynamic diameter of less than $2.5\ \mu\text{m}$ (PM_{2.5}) below the respective national ambient air quality standards. Measurement techniques in the former GDR did not allow distinctions of that kind. Therefore, the effects of particulate matters on the upper respiratory tract of East German schoolchildren could be attributable to larger particles, which are mainly derived from soil and crustal materials, or to fine particles produced by combustion of fossil fuels [15]. The reasons for any of these associations are unknown. Irritation due to inert or chemically active particles may induce non-specific inflammatory responses of the airway epithelium, resulting in respiratory symptoms such as running nose, cough and wheeze. Alternatively, damage to the epithelium of the upper respiratory tract may increase an individual's susceptibility to an infection with pathogenic agents.

Increased levels of SO_2 are often associated with high concentrations of other pollutants, such as particulate matters or acid aerosols. Therefore, the contribution of this compound to impaired respiratory health remains inconclusive. Some evidence of adverse effects of SO_2 , however, is derived from epidemiological and experimental studies. SO_2 is known to be removed from the inhaled airstream by uptake in the nasal mucosa [16]. By exposing allergic subjects to SO_2 by a face-mask, nasal work of breathing increased by about 30% [17]. Among children intermittently exposed to very high levels of SO_2 at moderate concentrations of particulate SO_4 , an increased prevalence of cough has been observed [18]. In the American Six Cities Study, a small effect of SO_2 on cough, but not on lower respiratory tract illnesses has been shown [6]. A recent study in Finland reported an increased prevalence of upper respiratory tract infections in infants and children living in a city polluted by moderate levels of SO_2 as compared to children of a clean air region [11]. Since in our analysis, two pollutant models including SO_2 and PM resulted in comparable risk estimates, as did the respective single pollutant models, collinearity of data may not account for the adverse effects of high mean concentrations of SO_2 in East German schoolchildren. It is not known what basic mechanisms mediate these adverse health effects.

Daily mean concentrations of NO_x showed a significant association with the prevalence of upper respiratory illnesses both in the high and the low concentration period, indicating that even low to moderate levels of nitrogen oxides may contribute to the inception of upper respiratory symptoms. Previous day levels were not associated with an increased risk. Our results confirm previous findings. SCHWARTZ *et al.* [10] reported a significant association between short-term fluctuations in NO_2 levels and short-term fluctuations in medical visits for viral croup in a longitudinal study in five German cities. Again, previous day concentrations were not related to the illness. BRAUN-FAHRLÄNDER *et al.* [9] demonstrated that the

duration of upper respiratory symptom episodes in healthy preschool children was related to NO₂. We previously reported an increased prevalence of colds in children exposed to heavy car traffic as compared to unexposed children in Munich, West Germany [19]. Air pollution by NO_x may act through alterations of the immune system in the lung through irritative or other processes. In animal models, high levels of NO₂ have been associated with reduced immunoresponses to infectious agents [20]. In humans, alveolar macrophages obtained by bronchoalveolar lavage after exposure of subjects to 0.6 ppm NO₂ showed reduced ability to inactivate influenza virus *in vitro* [21]. Interestingly, continuous exposure was more potent than the equivalent average dose delivered in short-term peaks.

In conclusion, the results of this study suggest that high concentrations of SO₂, and moderate levels of particulate matters and NO_x are associated with an increased risk of developing upper respiratory illnesses in childhood. A combination of high levels of different pollutants resulted in the highest risk. Furthermore, our findings indicate that recurrent upper respiratory illnesses may in part underlie the high prevalence of bronchitis and respiratory symptoms that have previously been reported in East German children [7, 8, 22].

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