

Nonallergic respiratory morbidity improved along with a decline of traditional air pollution levels: a review

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Nonallergic respiratory morbidity improved along with a decline of traditional air pollution levels: a review. J. Heinrich. ©ERS Journals Ltd 2003.

ABSTRACT: The tremendous decline of combustion-derived emissions of traditional air pollutants such as sulphur dioxide (SO₂) and total suspended particles (TSP) in Eastern Germany shortly after German reunification in 1990 provided the unique opportunity to study trends of prevalence of respiratory illness along with the improvement of air quality.

The present review focused on the results of two repeated surveys of nonallergic respiratory illness in children living in East Germany. The crude prevalence of respiratory illness such as lifetime bronchitis, otitis media, tonsillitis, frequent colds, and frequent cough decreased during the 1990s in East German children. For two surveys the effect estimates showed consistently statistically significant association of TSP with bronchitis. For SO₂ statistically significant associations with frequent colds were also consistently found, whereas at least one survey reported higher statistically significant effect estimates for tonsillitis, otitis media, frequent cough and reduced forced vital capacity.

The present study concludes that the prevalence of nonallergic respiratory illness in East German children is associated with sulphur dioxide and total suspended particles and that the improvement of air quality has beneficial effects on respiratory health.

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The German unification in 1990 has been a scientific opportunity to assess the effects of air pollution with a series of studies published since 1993. Some comparisons have been made with a neighbouring country, the Czech Republic.

Background: studies on air pollution effects in Germany during the 1990s

In East Germany ambient air pollution has been characterised by high concentrations of sulphur dioxide (SO₂) and total suspended particulates (TSP). Short-term effects of air pollution on daily mortality were investigated in Erfurt retrospectively for 1980–1989; logarithmic exposure-effect curves were found for both SO₂ and suspended particulates (SP) [1–3]. A Northern Bohemian coal basin study in the Czech Republic showed a 3.8% increase in mortality in association with 100 µg·m⁻³ TSP (lagged 2 days) for the time period 1982–1994 [4]. In Erfurt, from 1995–1998 short-term effect studies showed an increased mortality in association with the level of ambient air pollution, including ultrafine and fine particles [5]. The associations tended to be stronger in winter and at ages <70 yrs. The overall association for respiratory diseases was slightly stronger than for cardiovascular diseases. Following changes in the two major emission sources (coal burning for power production and heating, and motor vehicles), substantially decreased (19–91%) concentrations were observed for all pollutants, which may have led to decreased particle scavenging and, along with traffic-related changes, may be partially responsible for the observed increases in ultrafine particles [6, 7].

Whether the improved air quality with respect to level of TSP, particles with a 50% cut-off aerodynamic diameter of

2.5 µm (PM_{2.5}) and SO₂, and the temporally changed particle size distributions has an impact on short-term air population effects is a very attractive question, which needs further investigation.

Some panel studies [8, 9] showed associations of air pollution (ultrafine and fine particles) with decreased peak expiratory flow (PEF) and increased symptoms. Asthmatic children increased their β-agonist use with an increase of sulphates, but medication use did not prevent decreases in PEF and increases in the prevalence of cough attributable to particulate air pollution [10].

A recent published panel study of 53 adult asthmatics in Erfurt found increased use of corticosteroids with a cumulative exposure over 14 days of ultrafine and fine particles [11]. β₂-agonist use was associated with 5-day mean of ultrafine particle number concentration and fine particle mass. Also asthma symptoms were more frequently reported at days with higher fine particle concentrations [11].

Children residing in industrial towns of Hettstedt and Bitterfeld had increased lifetime prevalence for physician-diagnosed allergies, eczema, bronchitis, wheeze, shortness of breath, and cough without cold compared to children from Zerbst (less polluted control area). Sensitisation to common aeroallergens and specific immunoglobulin (Ig)E levels was more common for children from Hettstedt than from Zerbst [12, 13]. The annual mean TSP decreased from 1991 to 1998. The crude prevalence of bronchitis in the three respective areas decreased by 15%, 12%, and 11% between 1992 and 1995 [14]; prevalence of nonallergic respiratory symptoms also decreased for an extended follow-up until 1999, indicating the reversibility of adverse health effects [14, 15]. This adds further evidence to a causal association between combustion-related air pollutants and childhood respiratory symptoms.

In the framework of the multicentre European Community Respiratory Health Survey (ECRHS) the two German centres Erfurt (former East Germany) and Hamburg (former West Germany) were involved [16]. In the random sample of adults in Erfurt and Hamburg, 20–44 yrs, respiratory symptoms and diagnoses, bronchial hyperresponsiveness, atopic sensitisation (skin test and IgE), along with a lower mean number of siblings, a higher degree of childhood and current exposure to environmental tobacco smoke, and a higher frequency of fitted carpets and reported mould inside the house were more frequent in Hamburg than in Erfurt (higher pollution levels) [16].

In contrast to expectations in the early 1990s, the prevalence rates of asthma, hay fever and allergic sensitisation were found to be higher in the (less polluted) city of Hamburg compared with the (heavily polluted) city of Erfurt [16]. Comparative indoor measurements determine why the prevalence rates of asthma and allergies were increased in Hamburg.

Indeed, higher concentrations for mite and cat allergens were found in Hamburg compared to Erfurt [17]. These differences between Hamburg and Erfurt were accounted for mainly by different building characteristics (age of houses, building material, story, and size of the dwelling), as well as by differences in other individual living habits (keeping of pets, age of carpets or mattresses, and cleaning routines) [17]. Further, measured *Dermatophagoides pteronyssinus* antigen 1 (Der p 1) and *D. farinae* antigen 1 (Der f 1) concentrations differed between both cities and both mite allergen concentrations should be measured in house dust, since they are only weakly correlated and have different determinants [18]. No significant difference could be shown for the total and for single genera in concentration of spores of viable fungi [19].

Exposure to mite and cat allergens $>10 \mu\text{g}\cdot\text{g}^{-1}$ of mattress dust increased the risk of wheeze and breathlessness and cough at night in this study [20].

Nitrogen dioxide (NO_2) indoor concentrations in Hamburg were slightly higher than those in Erfurt [21]. The most important predictors of indoor NO_2 concentrations were gas cooking followed by other characteristics, such as ventilation, outdoor NO_2 level (motor vehicle traffic, especially in Hamburg), and environmental tobacco smoke. Conversely, indoor and outdoor median volatile organic compound (VOCs) concentrations in Erfurt were slightly, but significantly higher than those in Hamburg [22]. In general, the indoor VOCs air concentrations were significantly higher than the outdoor concentrations, except for benzene. In Erfurt and Hamburg beta (1 \rightarrow 3)-glucan concentrations in house dust were found to be correlated with endotoxins, mite and cat allergens, and cultivable mould spores [23]. Significantly increased concentrations were linked to: carpets in the living room, keeping a dog inside, use of the home by four or more persons, use of the living room for $>180 \text{ hr}\cdot\text{week}^{-1}$, lower frequency of vacuum cleaning and dust cleaning, and presence of mould spots during the past 12 months. Endotoxin concentrations in living-room floor dust sampled in homes without pets and vermin were lower than those sampled in homes with pets or vermin [24]. Endotoxin concentrations were higher in old buildings and in the lower storey of the dwelling, and were associated with longer occupancy in the apartment, high utilisation of the apartment during the sampling period, infrequent vacuum cleaning of the carpets, and an indifferent attitude to ventilation and keeping cats and dogs [25]. Summarising the results of comparative indoor measurements in Erfurt and Hamburg, it was concluded that despite detected regional differences, these differences probably only contribute a little to the different prevalences in atopic outcomes.

Additionally to the mite and cat allergens as typically

indoor allergens, grass pollen allergen were also measured in settled dust indoors. From randomly selected homes in Hamburg, Erfurt, Hettstedt, Zerbst and Bitterfeld during 1995–1998, the amount of grass pollen allergen in mass units (μg *Phleum pratense* antigen 5 (Phl p 5)) in dust settled indoors was detected in 67% of the samples analysed ($n=4,760$). Phl p 5 levels were significantly higher in the dust from floors than in mattresses. There were fluctuations of indoor Phl p 5 levels with a peak in June but also annual differences. There was a partially higher concentration of indoor allergenic activity several weeks after the grass-pollen peak. A positive association was found between Phl p 5 levels and total dust amounts throughout the year [26, 27].

In 1,884 term and normal-weight neonates, during the first 6 months of life, the risk of eczema was significantly decreased by elevated endotoxin exposure in dust from mothers' mattresses, whereas the risk was increased for respiratory infections and cough with respiratory infection, bronchitis, and wheezing (LISA (influences of life-life related factors on the immune system and the development of allergies in childhood) study; [28]).

Within the LISA cohort study there was an association between prenatal endotoxin exposure and IgE production [29]. Additional support for the important role which endotoxin exposure might play comes from a cross-sectional study, which found an association between exposure to higher levels of house-dust endotoxin with lower prevalence of allergic sensitisation in children [30]. However, other factors than indoor exposure might also be involved in the development of atopic disease [31, 32].

Background: studies on air pollution effects outside Germany

In comparison with the huge number of studies on short-term effects of air pollution, there are only a few studies investigating long-term effects of air pollution on respiratory morbidity in children. Most credible results come from cross-sectional studies including 24 communities from USA and Canada [33, 34]. These studies showed a positive association between bronchitis rates and lung function decrements (forced vital capacity (FVC), forced expiratory volume in one second) with fine particle strong acidity and particles with a 50% cut-off aerodynamic diameter of $10 \mu\text{m}$ (PM₁₀) (only lung function measures). These studies confirmed former results of chronic particle exposure and chronic cough, chest illness and bronchitis including fewer communities (Harvard six cities study [35, 36]). However, chronic effects on lung function have not been shown by these former studies [35–37]. Two recently published cohort study results on children's lung function and respiratory symptoms living in Southern California showed inconsistent results [38–41]. Whereas the cohort study by McCONNEL *et al.* [41] in 1999 reported statistically significant effects between exposure to PM₁₀ and bronchitis, phlegm and chronic cough in asthmatic children, studies by PETERS and coworkers [38, 39] did not find any statistically significant association between PM₁₀ and symptoms, but an association with lung growth was found in the study by GAUDERMAN *et al.* [40].

Cross-sectional studies in Switzerland, Germany and Poland have reported statistically significant associations between TSP, PM₁₀ and nonallergic respiratory symptoms [12, 42, 43] as well as between black smoke and SO_2 and slowed lung function growth [44]. Uncontrolled regional confounding might be a major source of the inconsistent results of different cross-sectional studies. Therefore, studies including more communities are less susceptible to unexplained differences

between geographical areas. Furthermore, the high correlation between different ambient air pollutants and the small number of included communities make it very difficult to separate pollutant specific effects.

Aim

Since the German reunification in 1990, the levels of SO₂ and TSP in Eastern Germany have declined tremendously [5, 6, 45], especially during the years 1990 and 1991. The closure of most of the industrial plants and the replacement of surface coal by natural gas for domestic heating contributed most to the decrease in SO₂ and TSP.

If ambient TSP and SO₂ levels were associated with a higher prevalence of bronchitic symptoms, and slowed lung function growth in children, a decline in these air pollution concentrations should produce a corresponding improvement of respiratory health. The current study reviewed results of repeated cross-sectional studies of nonallergic respiratory illness in children living in East Germany in order to examine the relationship between improvement of air quality and trends of prevalence of bronchitis, respiratory infections and adverse lung function measurements.

Methods

For the present review, repeated cross-sectional studies on East German children were looked at. Only studies which used identical methods in all surveys and which started before the middle of the 1990s, when air pollution levels were still quite high were considered for this review. Three studies were identified using children of different ages, but who were growing up in areas of the states of Sachsen and Sachsen-Anhalt (former East Germany) which are in close proximity.

Results

Table 1 gives an overview of the characteristics of the three reviewed studies. Examinations of >14,000 school beginners in each single school year 1991–1995 in four regions of Sachsen and Sachsen-Anhalt found a temporal decrease of prevalence of infectious airway diseases (bronchitis, tonsillitis, frequent colds, frequent cough) along with the strong decline in an annual mean of SO₂ (67 (rural)–240 µg·m⁻³ (urban) in 1989–1990 *versus* 54–76 µg·m⁻³ in 1993–1994) and TSP (70–102 µg·m⁻³ in 1989–1990 *versus* 46–53 µg·m⁻³ in 1993–1994)

Table 2. – Adjusted effect estimates for sulphur dioxide (SO₂) and total suspended particles (TSP) on nonallergic respiratory symptoms (as odds ratio (OR) per increments of SO₂ and TSP) and lung function (as means ratios in % per decrease of SO₂ and TSP) in the Bitterfeld Study (East Germany)

	Bitterfeld Study	
	SO ₂ per 100 µg·m ⁻³	TSP per 50 µg·m ⁻³
Respiratory illness		
Bronchitis (ever) ^{#,†}	2.72 (1.74–4.23)	3.02 (1.72–5.29)
Tonsillitis ^{#,‡}	n.e.	n.e.
Otitis media ^{#,†}	1.42 (0.94–2.15)	1.45 (0.89–2.37)
Frequent colds ^{#,§,+}	1.81 (1.23–2.68)	1.90 (1.17–3.09)
Frequent cough [#]	1.10 (0.73–1.64)	1.23 (0.82–1.84)
Lung function ⁺⁺		
FVC means ratio in %	4.9 (0.7–9.3)	4.7 (0.2–9.5)
FEV1 means ratio in %	3.0 (-1.1–7.2)	2.9 (-1.4–7.3)

Data are presented as adjusted OR (95% confidence intervals).

[#]: adjusted for age, sex, parental education, parental atopy, use of unvented gas cookers, dampness of flat, environmental tobacco smoke, contact with cats; [†]: lifetime; [‡]: past 12 months; [§]: defined as >2 in the Bitterfeld Study; ⁺⁺: repeated lung function measurements were performed only in sixth graders. Adjustment for height, season, lung function equipment, parental education, parental atopy, environmental tobacco smoke, and sex. FVC: forced vital capacity; FEV1: forced expiratory volume in one second; n.e.: not estimated. Source [15, 47].

[43]. Repeated cross-sectional studies of a total of 4,520 fourth graders in 1991–1992 and 1995–1996 revealed a decrease in the prevalence of bronchitis (32.2 *versus* 28.4%) and nocturnal cough (5.7 *versus* 5.1%) along with a decrease of an annual mean (1991 *versus* 1995) of SO₂ (240 *versus* 76 µg·m⁻³) and TSP (79 *versus* 53 µg·m⁻³) in the East German city of Leipzig [46]. Three repeated cross-sectional studies of a total of 7,611 East German children aged 5–14 yrs in the years 1992–1993, 1995–1996, and 1998–1999 found a statistical significant age-adjusted decrease for bronchitis (54.2 *versus* 38.0%), otitis media (30.7 *versus* 26.7%), sinusitis (4.6 *versus* 2.3%), frequent colds (36.7 *versus* 28.5%) and morning cough (13.4 *versus* 12.2%) in parallel to an improvement of annual means of SO₂ (60 *versus* 8 µg·m⁻³) and TSP (56 *versus* 29%) [15].

The design of two of these three studies allowed the contribution of ambient air pollution to the temporal changes of prevalence of respiratory illness to be modelled [15, 43]. In table 2 the effect estimates are given for SO₂ and TSP on

Table 1. – Characteristics of the reviewed studies

	Sachsen-Anhalt Study	Bitterfeld Study	Leipzig-Leipzig Study
Areas	Magdeburg, Halle, Leipzig, Altmark (low pollution level)	Bitterfeld, Hettstedt, Zerbst (low pollution level)	Leipzig
Primary study goal	Estimation of chronic effects of air pollution	Estimation of chronic effects of air pollution	Trends of prevalence of atopy
Years of examination	Trends of prevalence of atopy 1991, 1992, 1993, 1994, 1995	Trends of prevalence of atopy 1992–1993, 1995–1996, 1998–1999	1991–1992, 1995–1996
Age of children yrs	6–7	5–14	9–11
Subjects n (total)	14000	7500	3800
Participation rate %	64–96	75–89	82–88
Residential history >2 yrs	yes	yes	no
Air pollution decline %			
SO ₂	20–70	58–92	70
TSP	35–50	39–64	30
Reference	[43]	[12–15, 47]	[46]

SO₂: sulphur dioxide; TSP: total suspended particles.

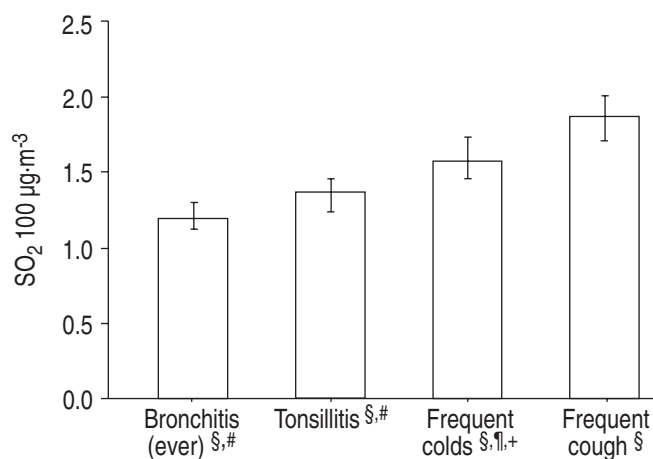


Fig. 1.—Adjusted effect estimates for sulphur dioxide (SO₂) on non-allergic respiratory illness (as odds ratio per 100 g increments of SO₂), in the Sachsen-Anhalt Study (East Germany) [43]. §: adjusted for age, sex, parental education, parental atopy, use of unvented gas cookers, dampness of flat, environmental tobacco smoke, contact with cats; #: lifetime; ¶: past 12 months; +: defined as >4 in the Sachsen-Anhalt-Study. Source: U. Kraemer, Institut fuer Umweltforschung, Duesseldorf, Germany, personal Communication and [43].

respiratory illness and lung function. The effect estimates of the Sachsen-Anhalt Study [43] were recalculated in order to guarantee comparability to the Bitterfeld Study (U. Kraemer, Institut fuer Umweltforschung, Duesseldorf, Germany, personal communication). They showed consistently a statistically significant increased risk for bronchitis and frequent colds per increase of TSP and SO₂. An increased risk per increase of SO₂ was also found in at least one survey for tonsillitis, otitis media, frequent cough and reduced FVC (table 2, fig. 1 and 2). An adjustment for time trend (only reported for the Sachsen-Anhalt Study [43]) changed the effect estimates only marginally. Furthermore, the steepest temporal decline in TSP and SO₂ was reported for those cities revealing the higher air pollution levels in the early 1990s [43]. One of these studies reported effect estimates stratified

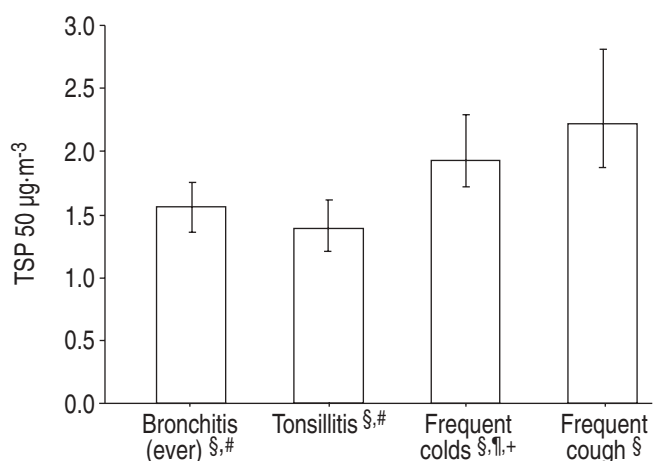


Fig. 2.—Adjusted effect estimates for total suspended particles (TSP) on nonallergic respiratory illness (as odds ratio per 50 µg increment of TSP) in the Sachsen-Anhalt Study (East Germany) [43]. §: adjusted for age, sex, parental education, parental atopy, use of unvented gas cookers, dampness of flat, environmental tobacco smoke, contact with cats; #: lifetime; ¶: past 12 months; +: defined as >4 in the Sachsen-Anhalt-Study. Source: U. Kraemer, Institut fuer Umweltforschung, Duesseldorf, Germany, personal Communication and [43].

for children with and without indoor exposures such as those derived from parental tobacco smoke, emissions from gas stoves, mouldy or damp homes or from cats. Children without these indoor exposure revealed higher effect sizes and had a greater benefit from the improvement of air hygiene levels than children who were exposed to at least one of these indoor pollutants [15]. The effect size estimates for FVC were also higher in children not exposed to these indoor factors [47]. These effect estimates could not be separated for SO₂ and TSP. The published effect estimates in the Sachsen-Anhalt Study were adjusted for each of the pollutants [43]. The SO₂ effect for bronchitis and the TSP effect for tonsillitis and frequent cough were no longer statistically significant [43].

Discussion

The uniqueness of these reviewed studies results from the sudden drastic decline in air pollution concentration a few years after the year 1989. In contrast to many other cross-sectional studies on long-term effects of ambient air pollution these studies have a rather unique design because in addition to the regional cross-sectional design they analysed temporal changes of respiratory morbidity along with improvements of air quality. The design lowered the risk of a bias caused by regional confounding, but increased a possible bias by temporal changes in morbidity rates.

Despite these differences, these findings are in close agreement with the results of studies in other geographic settings in the USA and Europe with different sources of air pollutants, using different air pollutant measurements and different epidemiological methods [48].

In these reviewed studies, statistically significant positive associations were found between particulate air pollution and nonallergic respiratory disorders such as bronchitis, frequent colds and chronic cough. These studies showed that increments of 10 µg·m⁻³ PM₁₀ were associated with a 5–25 per cent increase in bronchitis or chronic cough, whereas the highest increase of adverse health effects were reported for children [48]. The findings of the Bitterfeld Study correspond to a recalculated odds ratio of 1.24 for bronchitis for a 10-µg·m⁻³ increment in TSP, which is similar to the recalculated odds ratio of 1.20 for a 10-µg·m⁻³ increment in TSP (1.27 for a 10-µg·m⁻³ increment in particles with a 50% cut-off aerodynamic diameter of 15 µm (PM₁₅)) in the Harvard Six Cities Study [36], and lower than the odds ratio of 1.40 for a 10-µg·m⁻³ increment in PM₁₀ in children from the SCARPOL (Swiss Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution) study [42].

The authors of the Sachsen-Anhalt Study and the Bitterfeld Study attempted to disentangle age-related effects from birth-cohort-related effects on the prevalence of nonallergic respiratory illness. The adjusted prevalence of bronchitis increased continuously in all age groups and even within the three birth cohort subgroups which were born before 1990, the year of German re-unification [15]. All children investigated in the two other studies were born before the re-unification and were thus highly exposed during the 1980s. Nevertheless, even those children benefited from the improvements of air hygiene levels with increasing age. Presumably, the cumulative exposure a few years before the examination contributed more to health than an exposure in early infancy.

Each of these reviewed studies has several strengths and limitations. A major strength of all of these studies was that data showing strong improvement of air pollution levels within a rather short period could be used. Major limitations were the restriction of the analyses to TSP and SO₂ due to a

lack of data, the rather small number of included areas, and that one study was not originally designed to investigate health effects of ambient air pollutants.

The present study concludes that the prevalence of non-allergic respiratory illness in East German children is associated with SO₂ and TSP and that the improvement of air quality has beneficial effects on respiratory health.

Further studies are worthwhile in Europe to assess the temporal trends of the relationships of air pollution to respiratory health in another age-range of susceptible individuals, *i.e.* the elderly.

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