

Ambient air pollution and respiratory health in the east Baltic region

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Air pollutants of primary concern to human health in the east Baltic region include particulate matter and sulfur dioxide. Exposure to elevated levels of nitrogen dioxide and ozone is also widespread. Coal-fired power and heavy industrial plants not fitted with efficient air treatment equipment constitute major sources of air pollution. Domestic heating with coal causes high local levels in some areas. The rapid growth of motor vehicle traffic results in increased emissions, predominantly in densely populated areas. Several epidemiologic studies performed in the east Baltic region, mainly in Poland, have documented an association between air pollution exposure and adverse health effects, primarily in the respiratory tract. Short-term exposure to ambient air pollution has been related to an increase in mortality and hospital admissions for illnesses of the respiratory tract. The associations were mainly seen for particulates or sulfur dioxide, and thus they confirmed the findings from other parts of Europe and the United States.

Key terms health impact, international comparisons, outdoor air pollution, respiratory symptoms.

From both the clinical and public health perspective the most common environment-related health problems in the countries around the Baltic Sea concern exposure to excessive levels of air pollutants, and tens of millions of inhabitants are possibly affected (1). Ambient air pollution resulting from the combustion of fossil fuels includes emissions from power plants (stationary sources), motor vehicle engines (mobile sources), and household sources. Power plant emissions are largely responsible for atmospheric sulfur dioxide and for a complex array of respirable particulate matter. The latter includes nitrates, acid sulfates, and other sulfate salts generated secondarily in the atmosphere, metal salts and carbonaceous particles. Waste incinerators, smelters, and other industrial activities may be responsible for emissions of a variety of acidic, organic, and metallic compounds that cause local changes in air quality.

The main cause of air pollution in central and eastern Europe is the extended use of coal-fired power and heavy industrial plants that are not fitted with efficient air treatment equipment. However, current figures reveal that a sharp decline in industrial production following the economic difficulties of transition was accompanied by a decrease in air pollution levels (figures 1—2). In some central and eastern European countries, such as Poland, efforts aiming at implementing environmental protection

programs have brought about a substantial reduction in the emission of classical air pollutants (figure 3).

The available data on communal air pollution across western and eastern Europe are related to classical air pollutants in towns and big cities. Presumably, up to 30% of the European population can experience these pollutants in concentrations exceeding the daily air quality guideline levels of the World Health Organization (WHO), although for most of the people the exposure is limited to less than 30 days a year. The proportion of city residents with high long-term average levels were markedly higher in central and eastern Europe than in western countries (figures 4—5). The comparison of annual mean sulfur dioxide levels before and after 1985, for cities with data from both periods, as well as the trends from several other cities, indicates a decrease in the average sulfur dioxide pollution levels over the decade. The highest annual average concentrations reported at the end of the 1980s occurred in Leipzig (200 µg/m³). On the average, over 50% of the population living in cities in the former United Soviet Socialist Republic (ex-USSR) experienced days with pollution levels exceeding the daily guideline level of 125 µg/m³. In central and eastern Europe and the ex-USSR, the levels were higher than 200 µg/m³ on most of these days, and levels of >125 µg/m³ were more common than in western countries (1).

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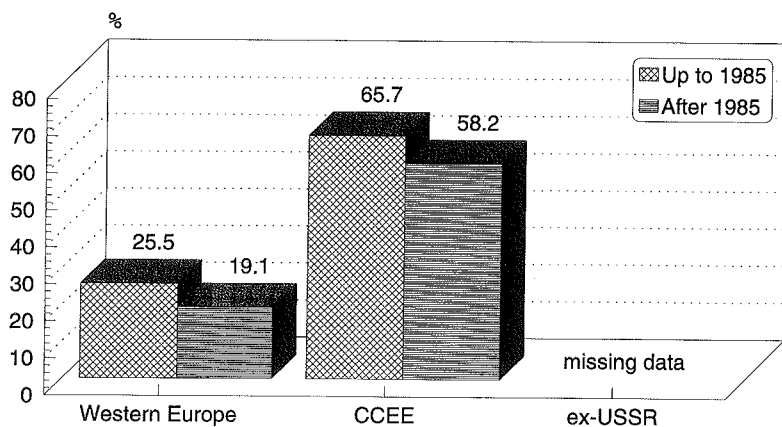


Figure 1. Exposure of the urban populations to suspended particulate matter (annual mean concentrations of suspended particulate matter $>50 \mu\text{g}/\text{m}^3$) [air quality guideline (annual mean concentration = $50 \mu\text{g}/\text{m}^3$) of the World Health Organization].

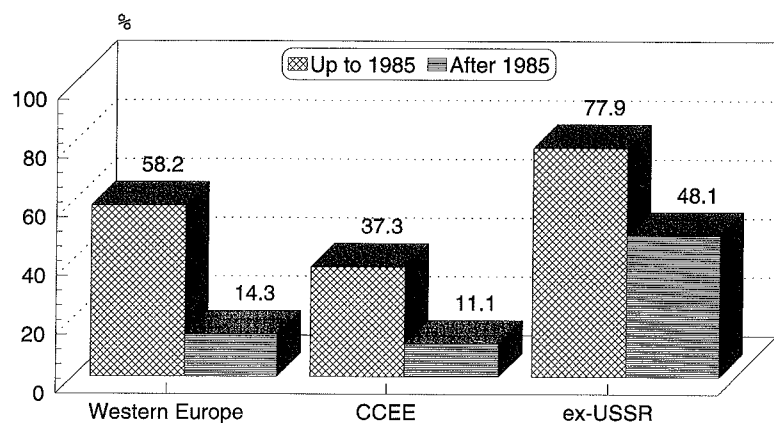


Figure 2. Exposure of the urban populations to sulfur dioxide (annual mean concentrations of sulfur dioxide $>50 \mu\text{g}/\text{m}^3$) [air quality guideline (annual mean concentration = $50 \mu\text{g}/\text{m}^3$) of the World Health Organization].

* / WHO air quality guideline (annual mean concentration) = $50 \mu\text{g}/\text{m}^3$

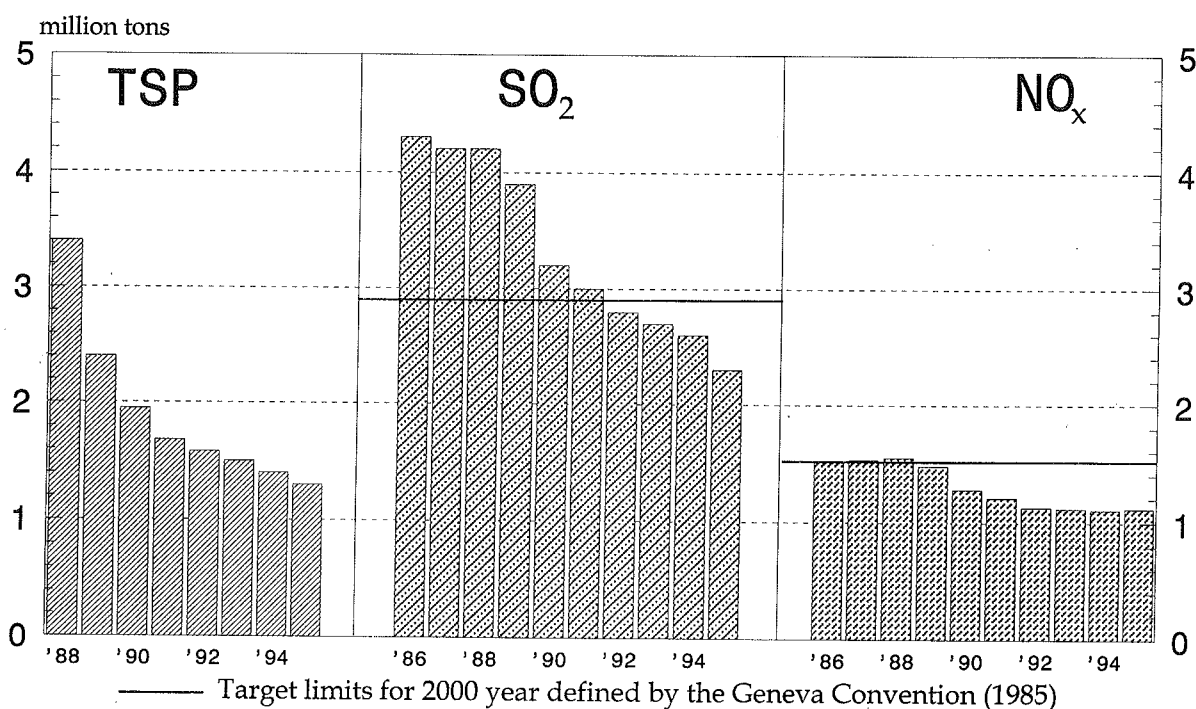


Figure 3. Trends in emission of total suspended particulate (TSP) matter, sulfur dioxide (SO₂) and nitrogen oxides (NO_x) in Poland over the last 10 years (1986—1995).

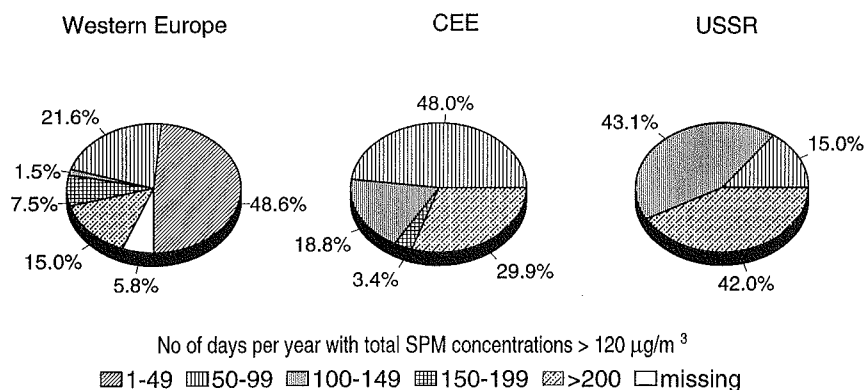


Figure 4. Percentage of city populations exposed to different numbers of days with total suspended particulate matter (SPM) >120 µg/m³, 1986–1991.

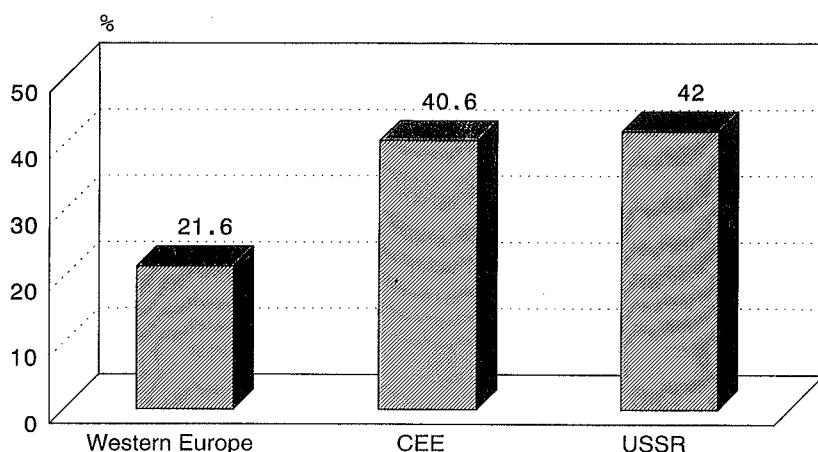


Figure 5. Percentage of the population with exposure to total suspended particulate matter at concentrations of >150 µg/m³ for at least 100 days a year.

Excess pollution was estimated for large parts of central Europe, the highest levels estimated being >350 µg/m³ for up to 10 days in the Black Triangle, an area between the former German Democratic Republic, ex-Czechoslovakia and Poland. In the northern Bohemia region of the Czech Republic, where low-grade coal is used for power generation and metal smelters predominate in industry, maximum concentrations of sulfur dioxide (1-hour measurements) can be as high as 2500 µg/m³ during inversion periods (150 µg/m³ being the maximum permissible level).

Health effects of outdoor air pollutants

Health effects due to air pollution are manifested in various ways, but mainly they pose a risk to the respiratory tract. Particles, sulfur dioxide, and acid aerosols form a complex group of pollutants that have common sources and usually co-vary in concentration. These air pollutants, possibly combined with other harmful agents and unhealthy life-style behavior, can damage the general health of the population, not only the respiratory tract.

The evidence linking air pollution to respiratory effects comes from a variety of disciplines, including epidemiology. Health effect end points include

cardiorespiratory mortality, morbidity as measured by hospital admissions or physician visits, symptom reporting, lung function testing, medication use, and altered host defense (table 1). The estimated effect of changes in air pollution levels on the various health end points is presented in table 2.

For some of the observed effects, the mechanisms and specific toxicants responsible remain unclear, for example, regarding the excess morbidity and mortality reported to be associated with increases in PM₁₀ (PM = particulate matter <10 µm). A recent hypothesis suggests that ultrafine particles may be particularly harmful, with effects mediated through the generation of free radicals and independent of particle composition. For example, particles of carbon black 20 nm in diameter have been shown to be capable of generating free radicals, as have samples of urban PM_{2.5}. Animal studies indicate that fine particles are associated with a wide variety of organic species and that, in some locations, aerosol nitrates and sulfates constitute a considerable fraction of the PM₁₀ (3).

Excess in cardiorespiratory mortality

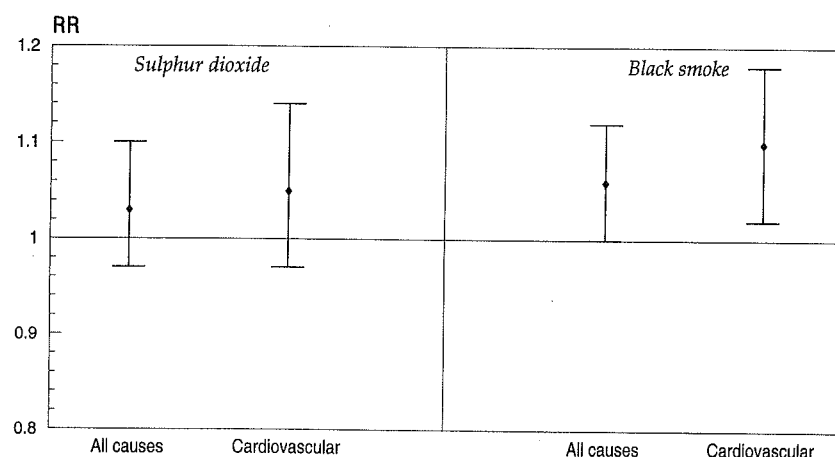
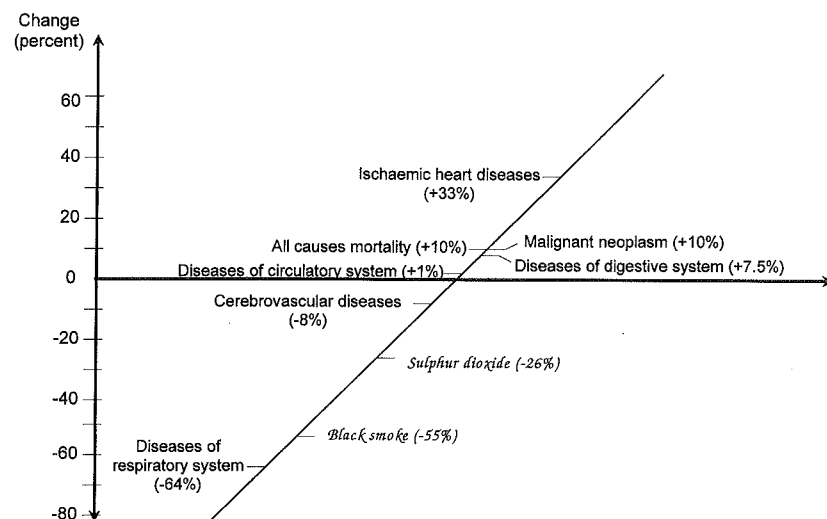
There is evidence coming from central and eastern European countries that a short-term increase in the

Table 1. Health effects and biological markers or response associated with air pollution.

Effect	Biological marker or response
1. Excess cardiorespiratory mortality	Death from heart or lung disease in excess of number expected
2. Increased health care utilization	Increased hospitalizations, physician visits, emergency department visits
3. Asthma exacerbations	Increased physician visits, medication use Decreased peak flow measurements
4. Increased respiratory illness	Increased respiratory infections, physician visits, episodic symptoms
5. Increased respiratory symptoms	
6. Decreased lung function	Spirometry, peak flow rates, airway resistance
7. Increased airways reactivity	Altered response to challenge with methacholine, carbachol, histamine, cold air
8. Pneumonia	Influx of inflammatory cells, mediators, proteins
9. Altered host defense	Altered mucociliary clearance, macrophage function, immune response

Table 2. Percentage of change in various health end points per 10 µg/m³ increase in concentration of particulate matter (PM) (2). (COPD = chronic obstructive pulmonary disease)

Health end point	Total suspended particulates	PM ₁₀	PM _{2.5}
Total daily mortality	0.6	1.1	1.7
Respiratory mortality	1.7	2.6	
Cardiovascular mortality	0.9	1.7	
Hospital admissions(all)			5.7
Hospital admissions asthma			3.5
Hospital admissions COPD in elderly		3.3	
Emergency room visits	0.3	3.4	
Bronchodilator use among asthmatics		7.0	
Symptom exacerbations among asthmatics		5.0	
Upper respiratory symptoms		1.5	
Lower respiratory symptoms		2.6	
Cough symptoms		2.4	
Peak expiratory flow		0.13	

**Figure 6.** Relative risk (RR) of death (and 95% confidence interval) associated with a 100 µg/m³ increase in the daily concentration of air pollutants in Krakow, 1992–1995.**Figure 7.** Mortality change over a 15-year period (1980–1994) for leading causes of death and change in air pollution level in Krakow, Poland.

concentration of a pollutant in the atmosphere, especially of particulate matter, may result in an increase in mortality in the days following the episode and that this phenomenon occurs even at moderate or relatively low pollutant levels (4). A study on the short-term effects of air pollution on mortality among inhabitants in Krakow over a 4-year period (1992–1995) has shown a significant positive association between mortality from all causes, as well as from cardiovascular diseases, and particulate matter measured by black smoke but not sulfur dioxide (figure 6). A similar analysis performed by Wojtyniak & Piekarski (5) in 4 major cities in Poland showed a clear relationship between black smoke and mortality in Lodz and Krakow; however, in other large cities (Poznan, Wroclaw) the positive association was much weaker.

It has been shown in a long-term monitoring study of adults in Krakow that a decrease in black smoke and sulfur dioxide levels in the city was associated with a downward trend in age-standardized respiratory mortality rates over 20 years. Although individual risk factors such as smoking habit or occupational hazards were not considered, the prevalence of cigarette smoking and employment in heavy industry did not change drastically over the study period (figure 7).

Increased respiratory morbidity

Epidemiologic studies concerning the acute effects of air pollution on health have been carried out in areas fraught with a potential smog hazard in the former East Germany. Bredel & Herbarth (6) and Herbarth (7, 8) published investigations on acute effects of air pollution over a period of 6 and 8 years, respectively. A significant correlation was found between air pollution measured by sulfur dioxide and specific morbidity as determined by emergency calls. The relationship between cases of illness of the respiratory tract, especially among children, and unfavorable air pollution was particularly marked. During smog situations concentrations of sulfur dioxide of more than 4.5 mg/m³ (30-minute average) or 2.5 mg/m³ (24-hour average) were observed. The findings were confirmed by an investigation carried out in another heavily polluted city (Halle), in which the same methods of analysis were applied. An increase in the number of emergency calls due to illnesses of the respiratory tract was observed at sulfur dioxide concentrations of 0.8 mg/m³ for adults and 0.24 mg/m³ for children (daily averages). The respiratory effects usually appeared with a time delay of 24 hours.

An analysis of association between number of daily office visits to a general practitioner and air pollution (sulfur dioxide, suspended particulate matter, nitrogen dioxide and fluorides) was carried out in Krakow (9). The

daily number of visits and specifically those due to respiratory diseases was clearly related to the sulfur dioxide concentrations. High concentrations of suspended particulate matter were associated with a greater number of visits due to cardiovascular effects, but only on warm days. Some association was also found for higher levels of nitrogen dioxide and fluorides with the number of visits.

Allergic disorders have been analyzed for 2800 children referred to the outpatient pneumonological clinic in Szczecin over a 5-year period (10). The authors found a higher frequency of visits due to allergic problems among very young children (<3 years old) living in the Police region than in the rural control area. In Police, with a big chemical plant producing fertilizers, the concentration of fluorides and sulfuric acid in the air was very high and greatly exceeded hygienic standards.

Increased respiratory symptoms in children and adults

Kleine (11), from former East Germany, demonstrated that there are spatial differences in the prevalence of some diseases of the respiratory tract in territories differing in air pollution. The data came from a questionnaire survey of children born in the regions of Bitterfeld and Wismar in 1982. Bronchitis, pseudocroup, and chronic cough were significantly more common in the children from Bitterfeld (3 times more frequent than in Wismar).

The respiratory function of 721 schoolchildren from a polluted region in former Czechoslovakia was examined by Bistraninova & Kotesovec (12). The authors found a seasonal variation in respiratory function values. The lowest values were observed in March, and it was assumed that this difference was due to the high degree of pollution in the preceding winter period.

Population studies comparing the prevalence of respiratory disorders in children 9–10 years of age have been carried out in 3 areas with differing air pollution levels in upper Silesia. In the less polluted area (Zawiercie) the prevalence of acute diseases of the upper respiratory tract was much lower (17.3%) than in the highly polluted towns (Chorzow, Olkusz), for which the rates were 55.6% and 66.0%, respectively. There was no correlation between the degree of air pollution and spirometric testing. The annual mean sulfur dioxide concentration in the most polluted town (Chorzow) was 174 mg/m³, in the less polluted town of Olkusz it was 11–96 mg/m³, while in the control area it was only 32 mg/m³ (13).

Sram (14), from the Czech Republic, published an epidemiologic study on respiratory effects of air

pollution in a large sample of 2nd, 5th, and 8th grade schoolchildren in the Teplice and Prachatice districts. The data showed that long-term exposure to high levels of classical pollutants was associated with an increased prevalence of cough and wheezing, as well as of wheezing bronchitis and asthma, but not of hay fever. Maternal smoking and childhood infections before 2 years of age were also associated with wheezy bronchitis and asthma. Odds ratio estimates for respiratory symptoms were significantly higher in the more polluted areas (figure 8). The study indicated that there is an interaction between living in a highly polluted area and maternal smoking in relation to childhood asthma. It should be noted that many children from the study were born during the early 1980s, when pollution levels in the district of Teplice were at maximal levels.

Several epidemiologic studies have been carried out on air pollution and respiratory diseases among adults in upper Silesia. One of these studies was performed on the population in urban and rural regions of the county of Toszek (15). Chronic bronchitis was found in 24.3% of the men and 7.5% of the women living in the city and in 19.8% in the men and 3.0% of the women from the rural region. Symptoms of chronic bronchitis were seen more frequently in the nonsmokers living in the town than in those living in the rural region.

Decrease in lung function

To evaluate the effects of ambient air pollution in Krakow on lung function was one of the objectives of a longitudinal study on chronic airway diseases (16–18). The study was based on a random sample of permanent Krakow residents, age 19–70 years in 1967. Interviewers using the Medical Research Council questionnaire collected data from 4355 subjects. Similar interviews were performed 13 years later (1981) with 3082 subjects (ie, 80% of the survivors of the original group). All the respondents were invited to spirometric testing. For 1824 subjects, a spirometric test was performed in both the

1968 and 1981 surveys. Data on ambient air pollution was obtained from routine measurements performed by the Sanitary-Epidemiological Station. The concentrations of particulate matter, measured as black smoke and sulfur dioxide, were measured in 17 locations in the city. Apart from the classical air pollutants, the sulfur transformation rate (STR) (ie, proportion of sulfate sulfur, SO_4^{2-} , in total sulfur) was also measured, and it can serve as a surrogate indicator of acid aerosols in ambient air. For the analysis of the relation between respiratory symptoms and ventilatory function and air pollution, the city was divided into areas A, B, and C. Area A, the eastern part of the city, had a high sulfur transformation rate (40%) and low concentrations of particulate matter and sulfur dioxide. Area B, the western part of the city, had an intermediate sulfur transformation rate (15%) at lower levels of particulate matter and sulfur dioxide. Area C, the central part of the city, had a low sulfur transformation rate (10%) and high concentrations of $\text{PM}_{2.5}$ and sulfur dioxide. The region with the highest levels of particulate matter (mean daily concentration 180 mg/m^3) and sulfur dioxide (mean daily concentration 114 mg/m^3) was situated within area C and was contrasted with the remaining part of the town, with mean concentrations of 109 and 53 mg/m^3 for particulate matter and sulfur dioxide, respectively.

The results of the analyses for the 3 areas of Krakow indicated that the decline in forced expiratory volume in 1 second ($\text{FEV}_{1.0}$) was related to the acid aerosol content. Area C, with a low sulfur transformation rate, and thus presumably with a low concentration of acid aerosols, was considered a reference area, and areas A and B, with higher sulfur transformation rates were treated as the exposed areas. It was found that the $\text{FEV}_{1.0}$ decline rate in the 13-year follow-up was significant in area A, which presumably had the highest level of acid aerosols. This effect was similar for smokers and nonsmokers, and it was not modified by the reported occupational exposures (table 3).

The Krakow follow-up study is the only one in Europe that has indicated a chronic effect of higher sulfate

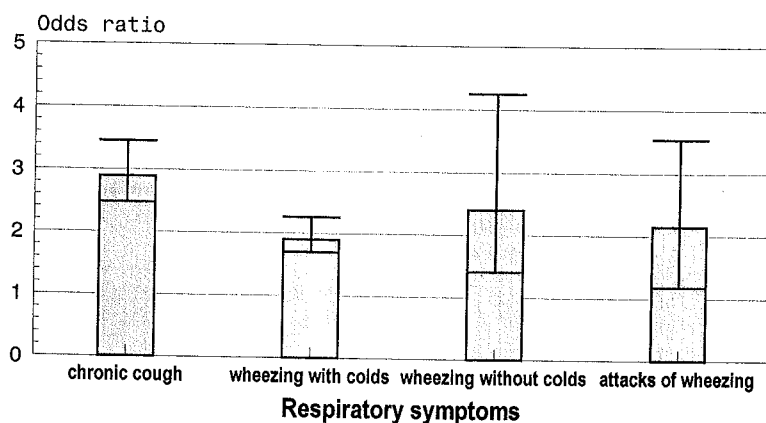


Figure 8. Comparison between the districts of Teplice (highly polluted region) and Prachatice (control area) for 7- to 16-year-old children.

content in urban air on lung function as strong as the detrimental consequences of smoking. It was evident from the additional analysis that the effect of sulfate pollutants and the sulfur transformation rate were not confounded by occupational hazards.

Exacerbations of asthma and atopy

Epidemiologic and controlled exposure studies of human volunteers have shown that exposure to a variety of pollutants induces asthma exacerbation. An interaction between pollutants and inhaled allergens, as well as an effect of pollutant exposure on base-line airway inflammation, may be important with respect to the pollutant-induced exacerbation of asthma. Further studies of this type of interaction, as well as of interactions between multiple pollutants, may be crucial for the rational development of intervention and regulatory strategies. Moreover, studies of sulfur dioxide exposure have shown that exercising asthmatic subjects are sensitive to brief exposures to sulfur dioxide. Some respond with bronchospasm to sulfur dioxide concentrations as low as 0.25 ppm; the bronchospasm is rapidly reversed by inhaled beta-adrenergic antagonists. However, such exposures do not appear to cause delayed or prolonged effects. The bronchoconstrictive response shares some features with exercise-induced bronchospasm in subjects with asthma, although the precise mechanism is not known (figures 9–10 on page 12).

Forsberg et al (19), in a study of the relation between asthma symptoms and air pollution on the basis of the registration of symptoms in diaries, have found that the risk of shortness of breath depends on the level of black smoke in the community after adjustment for weather conditions (temperature and humidity).

Numerous European studies have demonstrated an increasing prevalence of asthma during recent decades. The reason for this increase is not fully understood, but in Sweden changes in the indoor environment are likely to have contributed to the development. It has been suggested that an increase in the allergen load of the indoor environment has occurred. The most important domestic allergens in Sweden are those derived from furred pets and house dust mites. In several studies a relationship has been demonstrated between bronchial asthma and sensitization to furred pets (in the last 20 years in Europe there has been a 2-fold increase in the presence of household pets), as well as to house dust mites. In Sweden sensitization to furred animals is found in about 16–17% of schoolchildren, and for those with atopy or asthma the prevalence is 50% and 70%, respectively (20). During the last 10–15 years there has been a 2-fold increase in the prevalence of sensitization to house mites among at-

Table 3. Effect of residence in areas with various levels of air pollution on decline in forced expiratory volume in 1 second (FEV_{1.0}) between 1968 and 1981 (ml/year) estimated in linear regression models. (SE = standard error)

Factor	Men (N=584)		Women (N=830)	
	Coefficient ^a	SE	Coefficient ^a	SE
Area A (versus area C)	11.7**	3.7	11.8**	2.4
Area B (versus area C)	11.9**	4.0	3.9 [#]	2.4
Mean level of FEV _{1.0} (dcl)	-1.1**	0.2	-0.6**	0.2
Height (cm)	1.6**	0.3	0.7*	0.3
Continuous smoking (CCC)				
<15 cigarettes per day	14.0**	5.3	6.1*	3.7
>15 cigarettes per day	8.4*	3.8	8.7**	3.3
Exsmoking (CCE+CEE)	14.6**	4.5	0.8 [#]	4.2
Constant	-190.2	39.1		
R ²	10.5	4.8		

^a Significance of the regression coefficients: * 0.05 P<0.10, * 0.01 P<0.05, ** P<0.01; [#] Terms not significant (P>0.10) and included in the regression model.

opic children in Stockholm. Exposure to other risk factors, such as tobacco smoke and other environmental pollutants, is of importance and seems to increase the risk of atopic sensitization and asthma (21).

The prevalence of symptoms suggesting current asthma and asthma-related disorders was less common in Estonia than in other Nordic countries, although respiratory problems in general were more common. A comparison of Tartu with Uppsala revealed that the prevalence of atopy was lower in Tartu and the profile of antigens differed between the centers. There were also some differences in risk factors for atopy and allergic respiratory diseases (19). In the Kaunas administrative district of Lithuania (22), a study on asthma among 81 259 children and particulate air pollution was carried out. There were more cases of asthma among children under 15 years of age (6.5%) than in an area with lower levels of total suspended particulate matter (3.2%).

The association of asthma and chronic bronchitis with air pollution in residences was analyzed in a group of Polish military conscripts over 3 years (1979–1982) (23). A clear gradient of respiratory diseases was found with the sulfur dioxide concentrations, along with a high correlation for the rates of chronic bronchitis and asthma with the level of air pollution. Since the diagnostic criteria were based only on symptoms, a possible over-reporting of symptoms by recruits from towns casts some doubt on the reliability of the results.

The prevalence of atopic symptoms and positive prick tests among 642 schoolchildren (aged 10, 12, and 14 years) from urban and rural areas of Sundsvall, Sweden, was determined in 1988 (19). Urban living was a risk factor for at least 1 positive skin prick test to pollen or animal dander [odds ratio (OR) 1.83, 95% confidence interval (95% CI) 1.26–2.67]. Parental questionnaires, skin

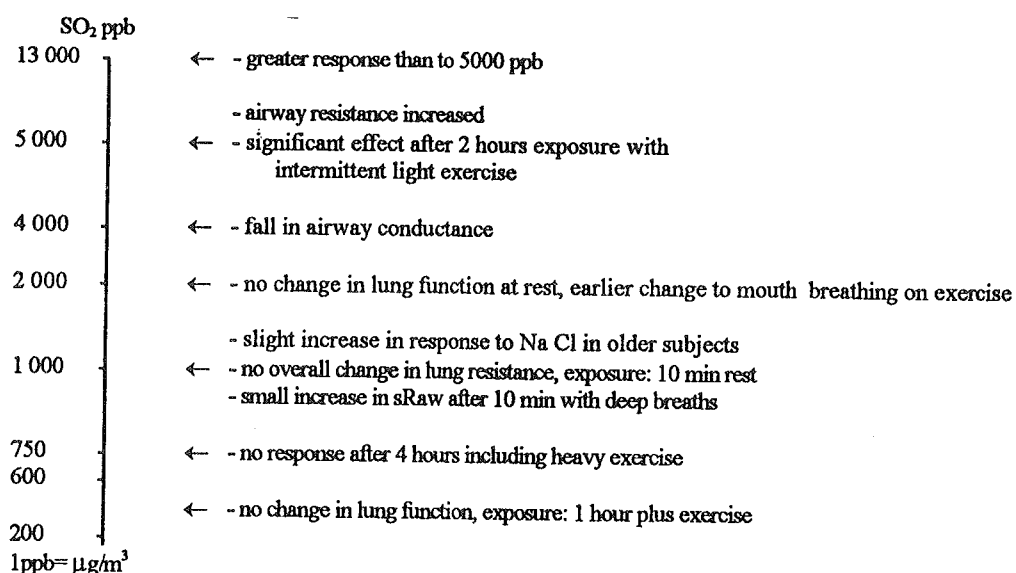


Figure 9. Concentration of sulfur dioxide at which changes in lung function occurred in normal subjects. [Adapted from *Sulfur Dioxide, Acid Aerosols and Particulates*, Department of Health, London, Stationary Office, 1992]

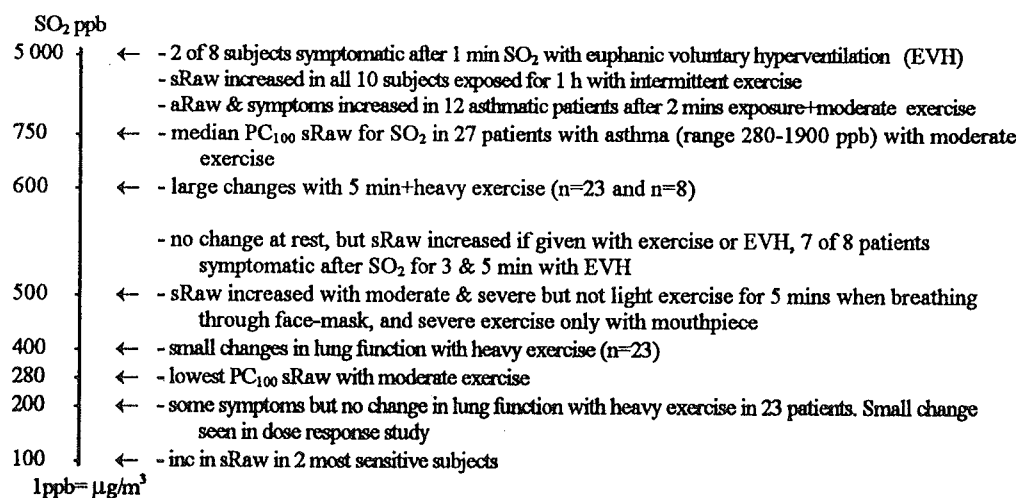


Figure 10. Concentration of sulfur dioxide at which changes in the specific airway resistance of the forced expiratory volume in 1 second or symptoms were seen in patients with asthma. [Adapted from *Sulfur Dioxide, Acid Aerosols and Particulates*, Department of Health, London, Stationary Office, 1992]

prick tests, and serial peak flow measurements were used in a study involving about 2600 10-to-12-year-old children from Sweden, Poland, and Estonia. The risk of a positive skin prick test was lower in the industrial center of Poland (Konin) and Estonia than in the urban area of Sweden (Sundsvall).

Recently, an interesting study has been published by Nowak et al (24) on the prevalence of respiratory symptoms, bronchial hyperresponsiveness, and atopy in a random sample of adults (20–44 years of age) from West and East Germany (Hamburg versus Erfurt). Within the time period from 1985 to 1989, the annual mean concentrations of sulfur dioxide and suspended particulate matter were 31 and 53 µg/m³, respectively, in Hamburg

as compared with 264 and 137 µg/m³, respectively, in Erfurt. A short respiratory questionnaire study was carried out with 3156 subjects (80% response rate) in Hamburg and 3274 (74% response rate) in Erfurt. In addition, a subset of respondents completed a long questionnaire, spirometry, a methacholine or bronchodilator test, a skin test, and total and specific immunoglobulin E (IgE) analyses, with a total number of 1159 participants in Hamburg and 731 in Erfurt (figure 11). There were more respiratory symptoms (wheezing, breathlessness, attacks of shortness of breath, attacks of asthma, nasal allergies) in Hamburg than in Erfurt, and in Hamburg the mean FEV_{1.0} (% of predicted) was lower (105%) than in Erfurt (107%). Bronchial hyperresponsiveness was observed significant-

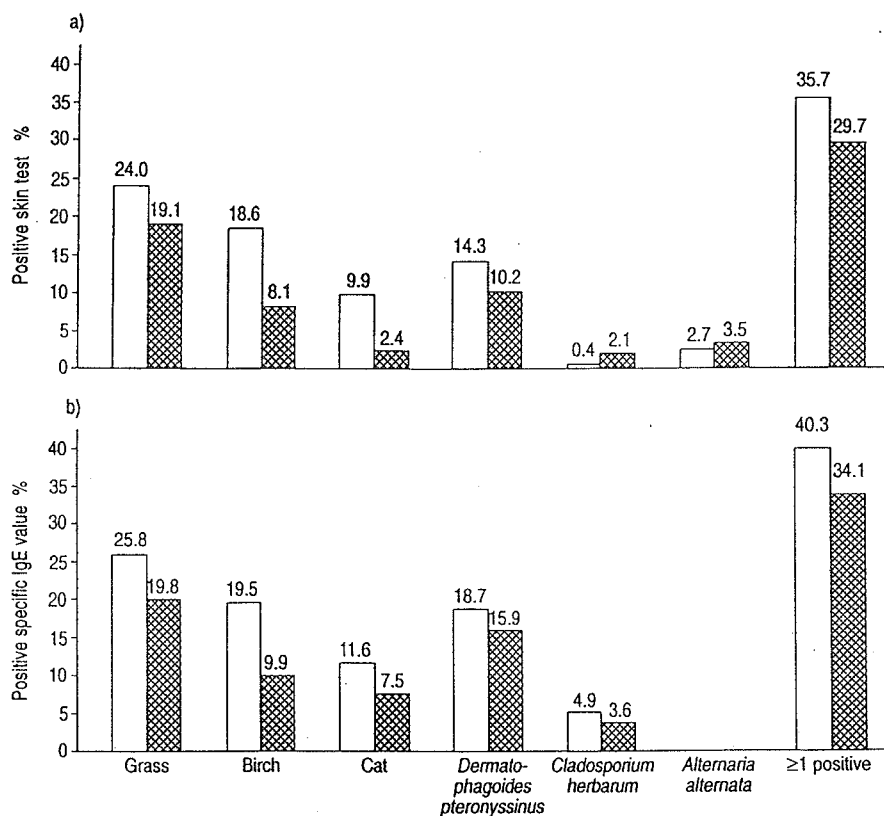


Figure 11. Prevalence of positive skin test reactions (wheal diameter ≥ 3 mm) (a) and of positive specific immunoglobulin E (IgE) values [>0.35 kU·l $^{-1}$; radioallergosorbent test (RAST)] in study participants from Hamburg and Erfurt (b). (open columns = Hamburg, closed columns = Erfurt) [Source: Nowak et al. Eur Respir J 1996;9:2541–52]

ly more often in Hamburg (25%) than in Erfurt (19%). Atopic sensitization was more prevalent in Hamburg than in Erfurt (against grass pollen 24% versus 19%, birch pollen 19% versus 8%, cat 10% versus 2%, and *Dermatophagoides pteronyssinus* 14% versus 10%). This finding was reflected by the prevalence of positive specific IgE values, which were higher in Hamburg than in Erfurt. In Hamburg, as compared with Erfurt, there was a lower mean number of siblings, higher current exposure to environmental tobacco smoke, and a higher frequency of wall-to-wall carpeting and a higher number of reports of mold inside the house. These data support the hypothesis that childhood factors and exposure to indoor allergens and irritants are more relevant for the development of asthma and atopy than potential long-term exposure to high concentrations of classic urban pollutants.

In another recent study in Krakow respiratory reactions to outdoor air quality among allergic and nonallergic children were evaluated (25). The purpose of the study was to assess whether the domestic air quality, together with the level of residential air pollution, increases the risk of allergy and whether allergy determines the occurrence of respiratory symptoms. An additional purpose of the study was to assess the extent to which allergy is related to outdoor air pollutants after adjustment for indoor air quality (environmental tobacco smoke or house mold). The survey targeted 1129 schoolchildren 9 years of age who attended schools located in areas of

Krakow that differed in their outdoor air pollution levels. According to measurements obtained from the air pollution monitoring stations and data from parents on sources of local emissions of air pollutants, 4 categories of air pollution were defined in the city.

The results showed that the prevalence of allergy among the children depended on parental allergy (OR 2.02, 95%CI 1.52–2.69) and house mold (OR 1.71, 95%CI 1.08–2.70). In addition, there was a statistically significant trend between the prevalence of allergy and the outdoor air pollution score (table 4). The prevalence odds ratio for allergy was 1.39 (95% CI 0.99–1.94) for the area with an air pollution score of 2 and 1.94 (95% CI 1.29–2.93) in the area with a score of 3. In terms of attributable fraction (AF), the effect of outdoor air pollution on the occurrence of allergy in children was significant [$AF_{(pop)}=21.8\%$].

Table 4. Effect of outdoor air pollution on the occurrence of allergy in children from Krakow as measured by the attributable fraction (AF) (population), adjusted for the confounding effect of molds in the house. (SE = standard error)

Outdoor air pollution	AF (%)	SE (%)	P-value
Score 1	2.11	3.55	0.277
Score 2	9.05	3.33	0.003
Score 3	10.70	2.39	0.000
Score 1–3	21.86	6.70	0.000

Lung cancer

In the highly industrialized Silesian region of Poland, severe environmental pollution is encountered that has been associated with increased risks of cancer. Polycyclic aromatic hydrocarbons (PAH) produced by the industrial and domestic combustion of coal are among the most prevalent carcinogenic and mutagenic air pollutants in Silesia. Yearly average concentrations of benzo[a]pyrene (BaP) at many measuring points in Silesia exceed, by a factor of 3–5, the concentrations of BaP found in a room of 36 m³ with a single air change per hour after the smoking of 40 cigarettes during an 8-hour day (26). Atmospheric concentrations of BaP in the town of Gliwice, for example, were 57 ng/m³ in winter and 15 ng/m³ in summer, the difference resulting from the considerable use of coal for heating. Accordingly, Perera et al, conducting a study in Silesia (Gliwice) and in the reference area (Biala Podlaska) found that BaP-DNA adducts in both the exposed and reference groups were higher in winter than in summer. They were also significantly higher in exposed winter samples than in reference winter samples, as were some markers of genetic damage.

In a case-referent study (27) of lung cancer deaths occurring over a 6-year period (1980–1985) in Krakow, Poland, it was indicated that urban air pollution may increase lung cancer risk and act multiplicatively with other factors such as smoking and industrial exposure. Information on occupation, smoking habits, and residence was collected from next-of-kin. The classification of exposure into community air-pollution categories was based on measured levels of total suspended particulate matter and sulfur dioxide (more than 120 µg/m³ for both areas with the highest levels). Lung cancer depended strongly on total cigarette consumption, on age at starting to smoke, and on time since stopping smoking. Relative risk

estimates for occupational exposure in iron and steel foundries and in other industries were clearly increased for men. The relative risk for men exposed to the highest air pollution level was 1.48 (95% CI 1.08–2.01), while for women the increase was lower (figure 12).

The results of this study received support in observations made later by Whyatt et al (28) in a molecular epidemiologic study in Krakow among infants. The study showed a dose-response association between urban air pollution level in Krakow and PAH-DNA adduct levels in white blood cells of cord blood. There was no clear dose-response for these levels when the total Krakow cohort of infants was grouped into low, medium, and high categories based on PM₁₀ levels at their place of residence. However, among infants of Krakow women not employed away from the home during pregnancy, adduct levels in the white blood cells of cord blood were clearly increased among infants residing in the medium [9.59 (SD 3.50)/10⁸ nucleotides] and high [6.53 (SD 1.98)/10⁸ nucleotides] pollution groups in comparison with the low pollution group [1.72 (SD 0.49)/10⁸ nucleotides]. Maternal adduct levels showed the same patterns. After control for smoking status, coal use, diet, and home or occupational exposure, the PAH-DNA adduct levels in white blood cells remained significantly higher in infants residing in the high than in the low pollution areas (figure 13). Similarly, a dose-related increase in placental CYP1A1 mRNA with ambient exposure was suggested.

A recent study by Zemlianaya et al (29) focused on lung cancer in relation to air pollution in Moscow. The risk factors for lung cancer were studied by the case-referent approach among women, and exposure to air pollution was based on measurements of sulfur dioxide, nitrogen dioxide, and carbon monoxide levels and total suspended particulate matter in the area of residence during the period 1971–1975. The risk of lung cancer was elevated for persons living in areas with heavy air

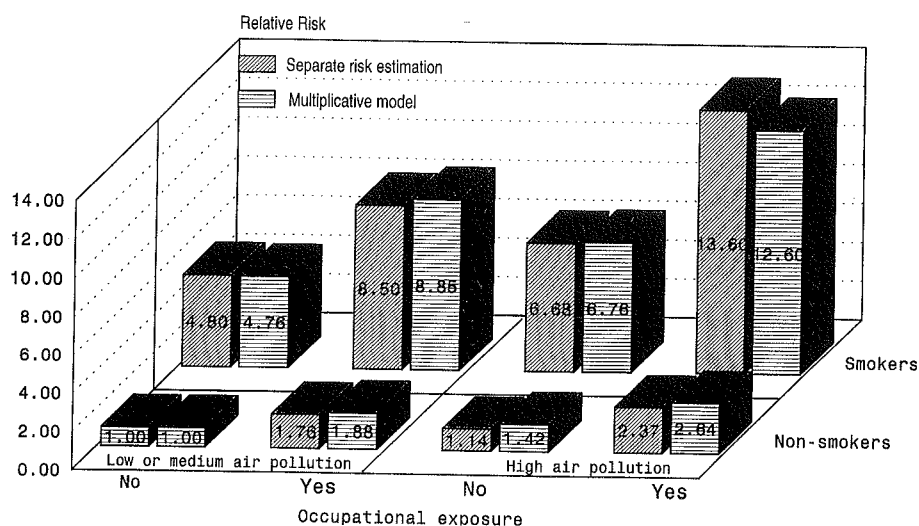


Figure 12. Multiplicative effect of smoking, occupational exposure and air pollution on the risk of lung cancer. [Source: Jedrychowski et al. *J Epidemiology Community Health* 1990;44: 114–20]

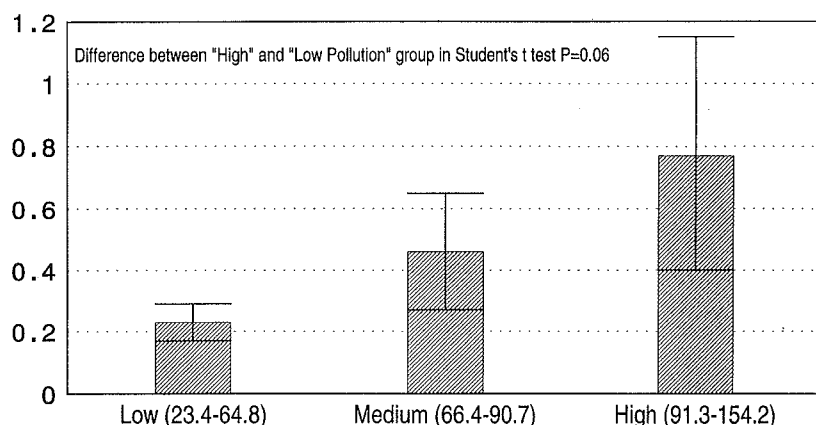


Figure 13. Placental CYP1A1 mRNA by level for PM₁₀ pollution the month prior to delivery for 66 mother-newborn pairs from Krakow, Poland. (PM = particulate matter) [Source: Whyatt et al. *Cancer Epidemiol Biomarkers Prev* 1995;4:147–53]

pollution (OR 2.42, 95% CI 1.2–4.8). Furthermore, a higher risk of lung cancer was observed for the women whose husbands smoked cigarettes (OR 1.66), but there was no effect of occupation.

Concluding remarks

This review has considered published papers or manuscripts prepared for publication dealing with air pollution and short- and long-term health effects on several health outcomes in the Baltic Sea region and elsewhere. There was evidence of an association between health effects and air pollutants; however, it is still unclear what the main causes are: sulfur dioxide, particulate matter, strong acidity aerosols, or sulfates.

An important limitation of the data is the great diversity in methods of air pollution exposure assessment used in the studies. Exposure is a function of ambient pollution, of indoor sources, and of the mobility of people from one microenvironment to another. Often only a limited number of outdoor monitoring sites provided estimates of exposure. Representativity of the stations for the exposure of the population was often poorly described.

Furthermore, the methods used for air pollution monitoring restricted possibilities for the comparison of studies using routine monitoring data. Particulate matter was measured and monitored rather as black smoke or total suspended particulate matter rather than as PM₁₀ or PM_{2.5}. Outdoor air pollution concentrations correspond to personal exposure to a limited extent, and indoor air quality and differences in smoking habits also contribute to regional differences in pollution exposure.

For several reasons, specific questions related to dose-response relationships were not addressed. Difficulties resulted from limitations in combining the results derived in regionally and otherwise different populations, the effect of pollutant mixtures, and the diversity of definitions of particular health points. Even though there is evidence

that the compounds can interact in a synergistic fashion to produce health effects, it was not easy to document this synergy from the studies under review.

Because air pollution in the Baltic Sea region affects several countries, we recommend regional studies be carried out rather than small within-country studies. Such studies should aim at (i) identifying the principal sources of health-threatening air pollutants in the region and then identifying a range of specific actions to reduce risks to the population from the pollutants, (ii) demonstrating how health risk considerations can be used to guide decisions about environmental priorities, policies, and investments, (iii) helping to build technical capabilities for conducting air quality management programs [it should be clear that risk assessment (hazard identification, dose-response assessment, exposure assessment, and risk characterization) will play a critical role], (iv) introducing standardized methodologies for environmental monitoring and for epidemiologic studies, including population exposure and risk assessment management.

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