ENVIRONMENTAL RESPIRATORY HEALTH IN CENTRAL AND EASTERN EUROPE

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SUMMARY

The main objective of the paper was to discuss the environmental issues in the countries of central and eastern Europe (CEE) and to show their significance for respiratory health. Many epidemiologic studies carried out in the region have documented an association between air pollution and adverse health effects in the respiratory tract. Short-term exposure to ambient air pollution has been related to an increase in mortality and hospital admissions for diseases of respiratory tract. Effects of long-term exposure was implicated in the rising trends of lower respiratory tract diseases, such as asthma and bronchitis, in both children and adults. Recent evidence indicates that the prevalence of allergic sensitization in the CEE countries is higher in urban than in rural areas. However, it is not clear to what extent ambient air pollution has contributed to this difference. It is difficult to estimate the toll of adverse health effects caused by air pollution in the CEE countries because of insufficient data on exposure. However, it is evident that significant positive effects would occur if air pollution concentrations in the region were reduced along with the WHO guidelines.

Key words: environmental health, respiratory diseases, ambient air pollution

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INTRODUCTION

From both the clinical and public health perspective the most common environment-related health problems in the countries in the former Eastern bloc concern exposure to excessive levels of air pollutants, possibly affecting tens of millions of inhabitants (1). Ambient air pollution resulting from the combustion of fossil fuels includes emissions from power plants (stationary sources), from motor vehicle engines (mobile sources), and from 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 (CEE) is the extended use of coal-fired power and heavy industrial plants that were 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 matching decrease in air pollution levels (Figs. 1, 2). In some CEE countries such as Poland, efforts aiming at implementing the environmental protection programs have brought about very substantial reduction in emission of classical air pollutants (Fig. 3). The available data on communal air pollution across Western and Eastern Europe are related to classical air pollutants being present in the towns and big cities. Presumably, up to 30% of the European population may experience these pollutants in concentrations exceeding the daily WHO air quality guidelines levels, though for most of the people the exposure is limited to less than 30 days per year. The proportion of city residents with high long-term average levels were markedly higher in the CEE than in western countries (Figs. 4, 5). The comparison of annual mean SO2 levels before and after 1985, for cities with data from both periods, as well as the trends from a number of other cities indicate a decrease in the average SO2 pollution levels over the decade. The highest annual average concentrations reported at the end of the 1980s were in Leipzig (200 µg/m³). On average, over 50% of the population living in cities in the former USSR experienced days with pollution
levels exceeding the daily guideline level of 125 μg/m³. In the CEE and ex-USSR, the levels were higher than 200 μg/m³ on most of these days and levels of over 125 μg/m³ were more common than in western countries (1). Excess pollution was estimated for large parts of central Europe; the highest levels estimated were above 350 μg/m³ for up to 10 days per year, and found 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 SO₂ (1-hour measurements) might be as high as 2 500 μg/m³ during inversion periods (150 μg/m³ is 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 on respiratory tract. Particles, SO₂, and acid aerosols are a complex group of distinct pollutants that have common sources and usually covary in concentration and change in parallel. These air pollutants, possibly combined with other harmful agents and unhealthy lifestyle behavior may damage general health of the population, not only respiratory tract.

The evidence linking the respiratory effects to air pollution comes from a variety of disciplines, including epidemiology. Health effect endpoints include cardiorespiratory mortality, morbidity as measured by hospital admissions or physician visits, symptoms reporting, lung function testing, medication use and altered host defense (Table 1). For some observed effects, the mechanisms and specific toxicants responsible remain unclear (for example, the mechanisms and specific toxicants responsible for the excess morbidity and mortality reported to be associated with increases in PM10). A recent hypothesis suggests that ultrafine particles may have unconventional toxicological properties. These effects may be mediated through the generation of free radicals and may be independent of particle composition. For example, 20 nm diameter particles of carbon black have been shown to be capable of generating free radicals as have samples of urban PM2.5. 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 (2).

EXCESS IN CARDIORESPIRATORY MORTALITY

There is evidence coming from CEE countries that a short term increase in the 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 occurs even at moderate of relatively low pollutant levels (3). The study on short term effects of air pollution on mortality among inhabitants in Krakow over 4-year period (1992–1995) has shown that there was significant positive association between mortality from all causes and from cardiovascular diseases and particulate matter measured by black smoke but not by SO₂ (Fig. 6). The similar analysis performed by Wojtyniak et al. (4) in 4 major cities in Poland has shown that there was significant relationship between black smoke and mortality in Lodz and Krakow, however, in other large cities (Poznan, Wroclaw) the positive association was not statistically significant.

It has been shown in a long-term monitoring study of adults in Krakow that a decrease in black smoke and SO₂ levels in the city was associated with the slowing down trends in age-standardized respiratory mortality rates over 20 years. Although the 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 (Fig. 7).

INCREASED RESPIRATORY MORBIDITY

Epidemiologic studies concerning 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 and Herbarth (5) and Herbarth (6, 7) 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 SO₂ and specific morbidity recorded 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 sulphur dioxide of more than 4.5 mg/m³ (30/min average) or 2.5 mg/m³ (24/h 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 in adults at 0.8 mg SO₂/m³ and in children

<table>
<thead>
<tr>
<th>Table 1. Health effects and biological markers or response associated with air pollution</th>
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<tr>
<td>1. Excess cardiorespiratory mortality</td>
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<td>Death from heart or lung disease in excess of number expected</td>
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<td>2. Increased health care utilization</td>
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<td>Increased hospitalizations, physician visits, emergency department visits</td>
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<td>3. Asthma exacerbations</td>
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<td>Increased physician visits, medication use</td>
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<td>4. Increased respiratory illness</td>
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<tr>
<td>Increased respiratory infections, physician visits, episodic symptoms</td>
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<td>5. Increased chronic respiratory symptoms</td>
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<td>6. Decreased lung function</td>
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<td>Decreased spirometry, peak flow rates, increased airways resistance</td>
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<td>7. Increased airways reactivity</td>
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<td>Altered response to challenge with methacholine, carbachol, histamine, cold air</td>
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<td>8. Lung inflammation</td>
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<td>Influx of inflammatory cells, mediators, proteins</td>
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<td>9. Altered host defense</td>
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<td>Altered mucociliary clearance, macrophage function, immune response</td>
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**Figure 6.** Relative risk of death (and 95% CI) associated with 100 µg/m³ increase in daily concentration of air pollutants in Krakow, 1992–1993.
at 0.24 mg SO\textsubscript{2}/m\textsuperscript{3} (daily averages). The respiratory effects usually appeared with a time delay of 24 h.

The analysis of association between number of daily office visits to a general practitioner and air pollution (SO\textsubscript{2}, SPM, NO\textsubscript{2} and fluorides) was carried out in Krakow (8). The daily number of visits and specifically those due to respiratory diseases was significantly related to SO\textsubscript{2} concentrations. High concentrations of SPM (suspended particulate matter) were associated with greater number of visits due to cardiovascular system but only in warm days. Some association was also found between higher levels of NO\textsubscript{2} and fluorides and number of visits.

The allergic disorders have been analyzed in 2,800 children referred to the outpatient pneumological clinic in Szczecin over 5 years period (9). The authors found the higher frequency of visits due to allergic problems among very young children (<3 years old) living in the rural control area. In Police, where very big chemical plant of fertilizers started to operate, the concentration of fluorides and sulfuric acid in the air was very high and exceeded manyfold hygienic standards.

**INCREASED RESPIRATORY SYMPTOMS IN CHILDREN AND ADULTS**

Kleine (10) from former East Germany demonstrated that there are spatial differences in the prevalence in 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 (three times more frequent than in Wismar).

The respiratory function in 721 schoolchildren was examined by Bistraninova and Kotásoví (11). The authors found a seasonal variation in respiratory function values. The lowest values were observed in March, and it was assumed that this was due to the high degree of pollution in the preceding winter period.

Population study comparing the prevalence of respiratory disorders in 9–10-year-old children has been carried out in 3 areas differing with air pollution level in the Upper Silesia. In the lower polluted area (Zawiercie) the prevalence of acute diseases of upper respiratory tract was much lower (17.3 %) than in the high polluted towns (Chorzow, Olkusz) where the rates were 55.6% and 66.0% correspondingly. There was no correlation between the degree of air pollution and spirometric testing. The annual mean SO\textsubscript{2} concentrations in the highest polluted town (Chorzow) was 174 \mu g/m\textsuperscript{3}, in the less polluted 11–96 \mu g/m\textsuperscript{3} (Olkusz), while in the control area only 32 \mu g/m\textsuperscript{3} (12).

Sárn et al. (13) from the Czech Republic published the results of the epidemiologic study on respiratory effects of air pollution in the large sample of 2\textsuperscript{nd}, 5\textsuperscript{th}, and 8\textsuperscript{th} grade schoolchildren in the Teplice and Prachatice districts. The data have shown that chronic exposure to high levels of classical pollutants was associated with increased prevalence of respiratory symptoms of cough and wheezing and 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 high polluted district Teplice than in the reference area of Prachatice (Fig. 8). The study indicated that there is an interaction between living in a highly polluted area and maternal smoking and this is a potential risk factor of asthma. It is necessary to mention that many children from the study have been born during the early 1980s, when pollution levels in the district of Teplice were at maximal levels.

In adults, a number of epidemiologic studies have been carried out on air pollution and respiratory diseases in the Upper Silesia. One of these studies was performed on the population of inhabitants of the urban and rural regions of the county Toszek (14) of men and 7.5% of women, of chronic bronchitis and asthmatic symptoms among residents living in the town.

**DECREASED MORTALITY**

Evaluation of chronic lung function was based on a random sample of age 19–70 years (15). The data were collected between 1980 and 1994. The number of the survivors was 80% of the survey. The correlation between the degree of air pollution and spirometric tests was performed on the urban population. The conclusion was that the increase of black smoke and SPM (suspended particulate matter) in the city, Apart from chronic lung diseases, the SO\textsubscript{2} in Krakow was a surrogate indicator of mortality.

The FEV\textsubscript{1} decrement was associated with the acid aerosol concentration. Areas as defined by the city air pollution regulatory strategy, presumably with the lowest mortality, were taken as a reference group. The districts of the AR, STR, and FEV\textsubscript{1} decline rates were treated as predictor variables. The results were analyzed using a multiple linear regression. The FEV\textsubscript{1} decline rate was faster by 12\% in the highest level of air pollution, while the AR and STR decreased by 7.5\%.

The Krakow study showed a strong correlation between the urban air pollution and chronic respiratory diseases. The correlation between the degree of air pollution and the AR and STR could not be explained by the increase in the prevalence of chronic obstructive pulmonary disease.

**EXACERBATION**

Epidemiologic studies of patients who induce asthma and inhaled allergic, asthma, baseline airway obstruction. This interaction, however, will be much lower than the airway obstruction. It is shown that exposure to SO\textsubscript{2} (as 0.25 ppm SO\textsubscript{2}) induces asthma and inhaled \beta-adrenergic receptor axis, although the extent of asthma and inhaled \beta-adrenergic receptor activity, exercise-induced asthma, and chronic obstructive pulmonary disease.

Numerous epidemiologic studies have found a correlation between the prevalence of chronic obstructive pulmonary disease and air pollution. The prevalence of chronic obstructive pulmonary disease is higher in areas with higher levels of air pollution. The correlation between the prevalence of chronic obstructive pulmonary disease and air pollution is stronger in areas with higher levels of air pollution.
County Torszek (14). Chronic bronchitis was found in 24.3% of men and 7.5% of women living in the city, and in 19.8% of men and 3.0% of women from the rural region. Symptoms of chronic bronchitis were seen more frequently in non-smokers living in the town than in those living in the rural region.

**DECREASE IN LUNG FUNCTION**

Evaluation of effects of ambient air pollution in Krakow on lung function was one of the objectives of the longitudinal study of chronic airways diseases (15-17). The study was based on a random sample of permanent residents of Krakow, age 19-70 years in 1968. Interviewers using the MRC questionnaire collected data from 4,355 subjects. Similar interview was performed 13 years later (1981) in 3,082 subjects, i.e. in 80% of the survivors from the original group. All respondents were invited to spirometric testing. For 1,824 subjects, the spirometric testing was obtained in both 1968 and 1981 surveys. Data on ambient air pollution were obtained in the routine measurements performed by the Sanitary-Epidemiological Station. The concentrations of particulate matter measured as black smoke and SO₂ were measured in seventeen locations in the city. Apart from the classical air pollutants, the sulfur transformation rate (STR), i.e., proportion of sulfate sulfur, SO₄²⁻, in total sulfur was also measured, and it may serve as a surrogate indicator of acid aerosols in ambient air.

The FEV₁ decline rate to air pollution levels was related to the acid aerosol content using the partition of Krakow into three areas as defined earlier. The area C, with low STR and thus presumably with low concentration of acid aerosols was considered as a reference area, and the areas A and B, with higher STR, were treated as the exposed ones. It was found that the FEV₁ decline rate in the 13-year follow-up was significantly faster by 12 ml/per year in the area A with presumably the highest level of acid aerosols. This effect was similar in smokers and in non-smokers, and it was not modified by the reported occupational exposures.

The Krakow follow-up study is the only one in Europe that showed the presumed chronic effect of higher sulfate content in the urban air on lung function was so strong as comparable with the detrimental consequences of smoking. It was evident from the additional analysis that the effect of sulfate pollutants and STR could not be 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 exacerbations. The interaction of pollutants and inhaled allergens and the effect of pollutant exposure on baseline airway inflammation may be a key mechanism of pollutant-induced exacerbation of asthma. Further studies of this interaction, as well as interactions of multiple pollutants, will be crucial for rational development of intervention and regulatory strategies. Moreover, SO₂ exposure studies have shown that exercising asthmatic subjects are sensitive to brief exposure to SO₂. Some respond with bronchospasms to as little as 0.25 ppm SO₂; the bronchospasm is rapidly reversed by inhaled β-adrenergic antagonists. However, such exposures do not appear to cause delayed or prolonged effects. The bronchoconstrictive response shares a number of features with exercise-induced bronchospasm in subjects with asthma, although the precise mechanism is not known.

Numerous European studies have demonstrated an increasing prevalence of asthma during the last three decades. The prevalence of symptoms suggesting current asthma and asthma-related disorder were less common in Estonia than in other Nordic countries, although respiratory problems in general were more common. Comparing Tartu with Uppsala revealed that the prevalence of atopy was lower in Tartu and profile of antigens differed between centers. There were also some differences in risk factors for atopy and allergic respiratory diseases (18). In Kaunas administrative district of Lithuania (21), the study on asthma in children in 1993 (81,259 children) and particulate air pollution has been carried out. There was more cases of asthma (6.5%) than in the area with lower level of TSP (3.2%) in children population under 15 years of age.

An association between asthma, chronic bronchitis and air pollution in residential area in the group of military conscripts has been analyzed over 3 years (1979-1982) in the whole Poland (22). The author found a clear gradient of respiratory diseases under study with SO₂ concentrations and almost perfect correlation of rates for chronic bronchitis and asthma with the level of air pollution in the place of residency. Since the diagnostic criteria were based only on symptoms, the possibly bias in overreporting the symptoms by recruits coming from towns makes the results less explicit.

In this study urban living was a risk factor for at least one positive skin prick test to pollen or animal dander, OR = 1.83 (95%CI:1.26-2.67). Parental questionnaires, skin prick tests and serial peak flow measurements were used in the study involving about 2,600 of 10–12-year-old children from Sweden, Poland and Estonia. The risk of positive skin prick test was lower in the industrial center of Poland (19) and Estonia than in urban area in Sweden (18).

Recently, an interesting study has been published by Nowak et al. (23) on the West-Eastern European differences in the prevalence of respiratory symptoms, bronchial hyperresponsiveness and atopy in the random sample of adults (20-44 years of age) in West and East Germany (Hamburg vs Erfurt). Within the time period from 1985 to 1989, annual mean concentrations of SO₂ and SPM were 31 and 53 μg/m³ respectively in Hamburg, as compared to 264 and 137 μg/m³ for SO₂ and SPM respectively in Erfurt. A short respiratory questionnaire study has been carried out in 3,156 subjects (80% response rate) in Erfurt. In addition, a subset of responders completed a long questionnaire, spirometry, methacholine or bronchodilator test, skin test, and total and specific immunoglobulin E (IgE), with a total number of 1,159 participants in Hamburg and 731 in Erfurt. There was 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 forced expiratory volume in one second (% of predicted) was lower (105%) than in Erfurt (107%). The study has shown that bronchial hyperresponsiveness (HR) was observed significantly more often (25%) than in Erfurt (19%). Atopic sensitization was more prevalent in Hamburg than in Erfurt (against grass pollen 24% vs 19%, birch pollen 19% vs 8%, cat 10% vs 2% and Dermatophagoides pteronyssinus 14% vs 10%). This was reflected by the prevalence of positive specific IgE values, which were higher in Hamburg than in Erfurt. In Hamburg, compared to Erfurt, there was a lower mean number of siblings, higher degree of childhood and current exposure to environmental tobacco smoke, and higher frequency of fitted carpets and reported moulds inside the house. These data may support the hypothesis that childhood factors and exposure to indoor allergens and irritants may have been more relevant for the development of asthma and atopy than the potential long-term exposure to high concentrations of classic urban pollutants.
In another very recent study in Krakow respiratory reactions to outdoor air quality in allergic and non-allergic children has been evaluated (24). The purpose of the study was to check the hypothesis whether the domestic air quality together with level of residential air pollution increases the risk of allergy and whether allergy determines the occurrence of respiratory symptoms. The additional purpose of the study was to assess to what extent allergy may be related to communal outdoor air pollutants after correction for indoor air quality (environmental tobacco smoke, or mold houses). The survey targeted 129 schoolchildren in the age of nine years who attended schools in Krakow located in the areas differing in outdoor air pollution level. Based on measurements obtained from the air pollution monitoring stations and data from parents on sources of local emission of air pollutants, four categories of air pollution areas have been defined in the city.

The results obtained document that the prevalence of allergy in children depended on parental allergy (OR = 2.02, 95%CI: 1.52–2.69) and molds in house (OR = 1.71, 95%CI: 1.08–2.70). In addition to that there was statistically significant trend with outdoor air pollution score.

**LUNG CANCER**

In the highly industrialized Silesian region of Poland, severe environmental pollution is encountered that has been associated with increased risk of cancer. Polycyclic aromatic hydrocarbons produced by industrial and domestic combustion of coal are among the most prevalent carcinogenic and mutagenic air pollutants in Silesia. Yearly average of BaP concentrations at many measuring points in Silesia exceed by 3–5 the concentrations of BaP found in a room of 36 m² with a single air change per hour after smoking 40 cigarettes during an 8 h day (25). Atmospheric concentrations of benzo[a]pyrene (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 control area (Biala Podlaska) has found out that BaP-DNA adducts in both exposed group and control group were higher in winter than in summer. They were also significantly higher in exposed winter samples than in control winter samples, as were some markers of genetic damage.

In a case-control study of lung cancer deaths occurring over a 6-year period (1980–1985) in Cracow Poland (26), it was disclosed that urban air pollution may increase lung cancer risk, acting multiplicatively with known factors such as smoking and industrial exposure. Information on occupation, smoking habits, and residence was collected from next-of-kin. Classification of exposure to community the high air pollution category (more than 120 µg/m³ TSP and SO₂) was based on measured levels of total suspended particulate matter and sulfur dioxide. 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 significantly increased in males. The relative risk in men exposed to the highest air pollution level was 1.48 (95% confidence interval 1.08–2.01), while in women the increase was not significant.

In fact, the results of the above mentioned study find a support in observations made later by R. Whyatt et al. (27) in the molecular epidemiologic study in Cracow among infants. The study showed a dose-response association between urban air pollution level in Krakow and cord blood benzo[a]pyrene (BaP) adduct levels. There was no clear dose-response in cord blood BaP-DNA adduct levels when the total Krakow cohort of infants was trichomized into low, medium and high 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 cord blood were significantly increased among infants residing in the middle (9.59 ± 3.50 per 108 nucleotides) and high (6.53 ± 1.98 per 108 nucleotides) compared to low pollution group (1.72 ± 0.49 per 108 nucleotides). This was similar to results seen with maternal adduct levels. After controlling for smoking status, coal use, diet and home/occupational exposure, WBC benzo[a]pyrene-DNA adduct levels remained significantly higher in infants residing in the high compared to the low pollution group (Fig. 9). Similarly, a dose-related increase in placental CYP1A1 mRNA with ambient exposure was suggested.

Recent study was published by Zemlianaya et al. (28) on lung cancer related to air pollution. Risk factors for lung cancer were studied by case-control approach among females and exposure to air pollution was based on measured SO₂, NO₂, CO and TSP in the area of the residence for the period 1971–1975. Risk of lung cancer was elevated in persons living in areas with heavy air pollution (OR = 2.42, 95%CI:1.2–4.8). It was shown significantly higher risk of lung cancer in women whose husbands smoked cigarettes (OR = 1.66) and there was no effect of occupation.

![Fig. 9. Placental CYP1A1 mRNA by level of PM₁₀ pollution the month prior to delivery for 66 mother/newborn pairs from Krakow, Poland.](image-url)
CONCLUDING REMARKS

In the review, the published papers or manuscripts prepared for publication dealing with air pollution and short- and long-term health effects on several health outcomes have been considered. There was a good evidence for an association between health effects and air pollutants, however, there is still unclear what are the main causes of poor health effects: sulfur dioxide, particulate matter, strong acidity aerosols or sulfates.

An important limitation of the study 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 movements of the individuals from one micro-environment to another. Often only a limited number of outdoor monitoring sites provides estimates of exposure. Representatively location of the stations for exposure of the population was also poorly described.

Further, the methods of 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 particles than as PM10, or PM2.5. 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.

In the review of the studies we could not address specific questions related to the dose-response relationship. These difficulties resulted from limitations in combining the results derived in regionally and otherwise different populations, effect of pollutant mixtures and diversity in definitions of particular health points. Even though there is evidence that the compounds can interact in a synergistic way to produce health effects, it was not easy to document this from the studies under review.

Because air pollution in the region affects several countries, it is recommended to carry out rather regional studies than small ones within one-country. These studies should aim at: 1. identifying the principal sources of health threatening air pollutants in the region and then to identify a range of specific actions to reduce risks to the population from those pollutants, 2. demonstrating how risk considerations can be used to guide decisions about environmental priorities, policies, and investments, 3. 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, 4. introducing standardized methodologies for environmental monitoring and for epidemiological studies including population exposure and risk assessment management.

REFERENCES


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