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EFFECT OF RESIDENTIAL PROXIMITY TO TRAFFIC ON RESPIRATORY DISORDERS IN SCHOOL CHILDREN IN UPPER SILESIAN INDUSTRIAL ZONE, POLAND

MICHAŁ SKRZYPEK[1], JAN E. ZEJDA[2], MAŁGORZATA KOWALSKA[2], and ELŻBIETA M. CZECH[1]

[1] Medical University of Silesia, Katowice, Poland
Department of Biostatistics
[2] Medical University of Silesia, Katowice, Poland
Department of Epidemiology

Abstract
Objective: A number of studies show an association between traffic-related air pollution and adverse respiratory health effects in children. However, most evidence relates to the regions with low or moderate levels of ambient air pollution. The study was undertaken to assess the impact of traffic-related air pollution on respiratory health status in children living in the area of high levels of industrial and municipal ambient air pollution. **Materials and Methods:** Analyses involved data obtained from cross-sectional study on respiratory health in children (N = 5733), conducted between 2003–2004 in Bytom, one of the largest cities of Silesian Metropolis (Poland). Exposure to traffic-related air pollution was assessed by means of geographic information system and expressed as several measures of potential exposure to traffic-related air pollution, involving residential distance to major road and traffic density in the residential area. Logistic regression was used to examine association between reported respiratory health and traffic measures. **Results:** Statistically significant association was found between doctor-diagnosed asthma and residential proximity to traffic. Results of multivariate logistic regression (logOR; 95%CI) confirmed the effect of living in an area of a city with high-traffic-density on childhood asthma: 1.60 (1.07–2.39). Similar effects were found in case of allergic rhinitis and rhinitis symptoms, but the observed associations were not statistically significant. **Conclusion:** The study findings suggest that even in an area with poor regional ambient air quality, adverse respiratory health outcomes are more frequent in children living in a proximity to the high vehicle traffic flow.

Key words:
Air pollution, Road traffic, Children, Respiratory health, Asthma, Allergic rhinitis

INTRODUCTION

Respiratory health effects of children's exposure to traffic-related air pollution have been a topic in respiratory epidemiology for a number of years. Published reports provide evidence concerning a number of disorders, including exposure-related occurrence of asthma and other respiratory diseases [1–7]. Symptoms suggestive of asthmatic tendency as well as diagnosed asthma or hospital admissions due to asthma were found to depend on exposure to traffic-related air pollution expressed by traffic intensity or by a distance of children's residence from the main road [8–11]. Published reports usually focus on populations living in areas of relatively low background ambient air pollution. It remains unknown if the respiratory effect of exposure to traffic-related air pollution can be identified in populations exposed to increased background ambient air pollution from industrial and household sources. In order to explore that issue, we analysed survey data collected in 2004 in urban children,

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Corresponding author: M. Skrzypek, Department of Biostatistics, Medical University of Silesia, Piekarska 18, 41-902 Bytom, Poland (e-mail: mskrzypek@sum.edu.pl).

living in the central part of Upper Silesian Industrial Zone (USIZ, Katowice, Poland) known for long lasting industry-related environmental pollution. Mean annual air pollution concentrations determined during the respiratory survey were high [12].

As a result of effective environmental protection measures, the levels of ambient air pollution have substantially declined over the last decade. At the same time however, both volume and intensity of vehicle traffic have rapidly increased in this area, both because of an increasing number of vehicles and unchanged road infrastructure [13].

The goal of the study was to discover if the occurrence of respiratory diseases and symptoms in children living in USIZ was associated with surrogate indices of exposure to traffic-related air pollution, represented in terms of residential distances from the roads, traffic intensity or density.

MATERIALS AND METHODS

The cross-sectional study was performed in the town of Bytom (central part of USIZ; total population: 190 292 inhabitants). In 2003–2004 all children aged 7–14 years attending primary schools in Bytom were asked to participate in a school-based general health survey. The questionnaire included a limited number of questions on respiratory health selected from the Polish version of the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire. Parents or legal guardians of 16 356 children received invitation to participate in the study together with written informed consent and were asked to fill in the questionnaire. Questionnaires were returned by 11 209 (68.5%) responders; 3070 (27.4%) were removed from the database (N = 11 209) due to missing data. Moreover, 2406 (21.5%) children were excluded from the analysis due to the central location of their residence within the city. This restriction resulted from the significant differences between studied subjects and excluded group in the environmental exposure to pollution, such as coal heating or tobacco smoking, and socio-economic determinants (Table 1).

The children's respiratory health was determined according to answered questions about ever physician-diagnosed asthma, allergic rhinitis, and according to the occurrence of respiratory symptoms. The list of

Table 1. Demographics, home environmental factors, family history of respiratory diseases of studied children in comparison with non-participant responders

Characteristic	Studied children (%)	Non-participant responders (%)	χ^2 p
Gender			
female	50.6	50.2	0.71
Socioeconomic status			
low financial family standing	53.8	64.0	< 0.01
maternal education (below high school)	51.4	60.9	< 0.01
paternal education (below high school)	63.8	70.9	< 0.01
Indoor environment			
coal or gas heating	25.2	60.3	< 0.01
environmental tobacco smoke	53.4	62.0	< 0.01
Family history			
parental respiratory illness	6.2	8.6	< 0.01
parental allergy	10.1	10.1	0.99

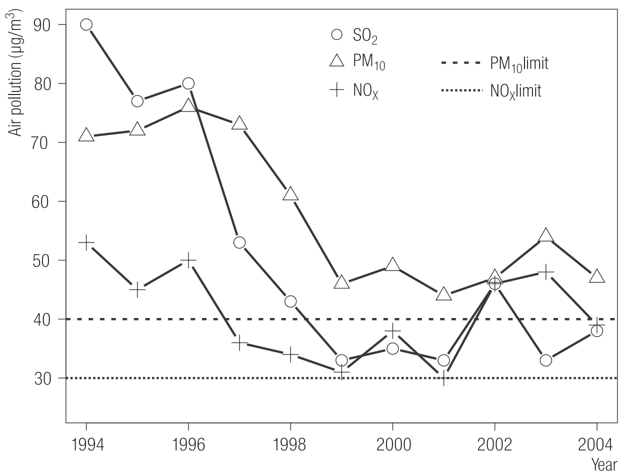

Fig. 1. Mean annual air pollution concentrations in the city of Bytom

analysed symptoms included attacks of dyspnoea ("Has the child ever had attacks of shortness of breath?"), chest wheeze ("Has the child ever had chest wheezing or whistling?"), persistent cough ("Does the child have cough, apart from a cough associated with a cold or chest infection?"), rhinitis symptoms ("Does the child sneeze or have a runny nose, apart from symptoms during a cold or chest infection?"). Figure 1 shows changes in mean annual air pollution concentrations in the period 1994–2004; please note that the annual average exceed the limit value for particulate matter (PM_{10}).

Based on questionnaire-derived residential addresses, the place of residence for each subject was identified by means of geographic information system (ESRI ArcGIS, version 9.2). Statistical analyses were performed for 5733 observations with complete data on respiratory health. Spatial distribution of the study group is shown in Figure 2.

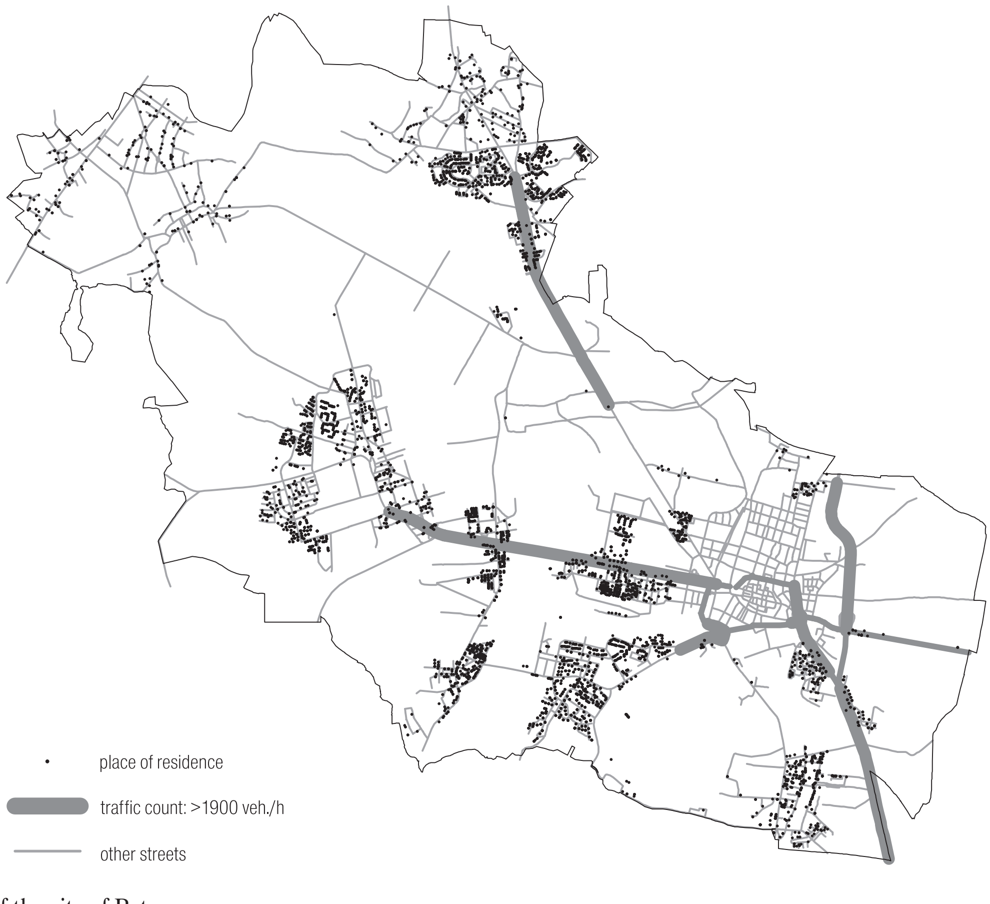

Fig. 2. A map of the city of Bytom

Specific data on traffic intensity on the majority of streets in the town were obtained from the records available at the municipal office in Bytom. The data included the number of cars travelling per hour in both directions along a given road segment during rush hour. There are two major regional roads in Bytom conveying traffic along east-west and south-north directions. On the basis of traffic volume measures, busy roads were defined as 95th percentile of the distribution of traffic volume, which included roads with traffic intensity of 1900 vehicles per hour and more.

For all subjects, residential distances from busy roads were calculated and divided into the subsequent categories: ≤ 100 m and > 100 m, usually used for exposure assessment [9,14–17]. The following GIS-based indicators were used as surrogates of exposure to traffic-related air pollution:

- Model A: the distance of a child's residence to major road [5] expressed as a categorical variable (≤ 100 m and > 100 m),
- Model B: the highest traffic count within 100 m radius of the place of residence [18] expressed as a categorical variable (> 90th percentile and ≤ 90th percentile of traffic counts),
- Model C: the traffic density within 100 m radius of the place of residence [19,20] was calculated as:

$$TD = \frac{\Sigma(N \times L)}{A} \quad (1)$$

where:

TD – a traffic density (vehicles × km/h/km²),

N – the hourly traffic count (vehicles/h),

L – the length of street segment (km),

A – the area of the 100 m buffer around the place of residence (km²), also expressed as a categorical variable (> 90th percentile and ≤ 90th percentile of traffic densities).

All exposure models were used to compare the prevalence of respiratory diseases and symptoms between subjects categorized into either exposure or control group. Statistical significance of between-group differences was assessed using χ^2 test. The potential confounding effects like: gender, age, financial family standing (good/poor), maternal and paternal education (below secondary, otherwise), type of heating (coal-based/central), exposure to environmental tobacco smoke at home (yes/no), parental history of chronic respiratory disorders (yes/no), and parental history of allergic disorders (yes/no) were controlled by means of multivariate logistic regression. The stepwise selection method of model building was used, with significance level set to $p = 0.2$ to allow a confounder into the model, and significance level set to $p = 0.1$ for a confounder to stay in the model. For each effect of exposure variable on respiratory outcome, the logistic odds ratio (logOR) and their 95% confidence intervals (95% CI) were calculated. Interpretation of statistical significance was based on the criterion $p < 0.05$. All statistical analyses were performed using SAS, version 9.2 (SAS Institute Inc., Gary, NC).

RESULTS

Almost all children (90%) lived in Bytom since birth, whereas only 1% emigrated to the town within a 3-year period before the survey. Table 1 shows gender, age, and socioeconomic status, family history of respiratory and allergic diseases in all 5733 children.

Exposure Model A identified 452 children living within 100 m from the main road defined by the 1900 vehicles per hour cut-off and 5281 children in the control group. Exposure Model B identified 494 children living in the area within 100 m from the roads where maximum traffic intensity exceeds 90th percentile of traffic counts for all roads and 5239 children in the control group. Exposure Model C identified 505 children living in the area within 100 m from the roads where traffic density is greater than 90th percentile of the traffic density calculated for all roads and 5228 children in the control group. Figure 3 presents overlapping of exposed groups in these three models.

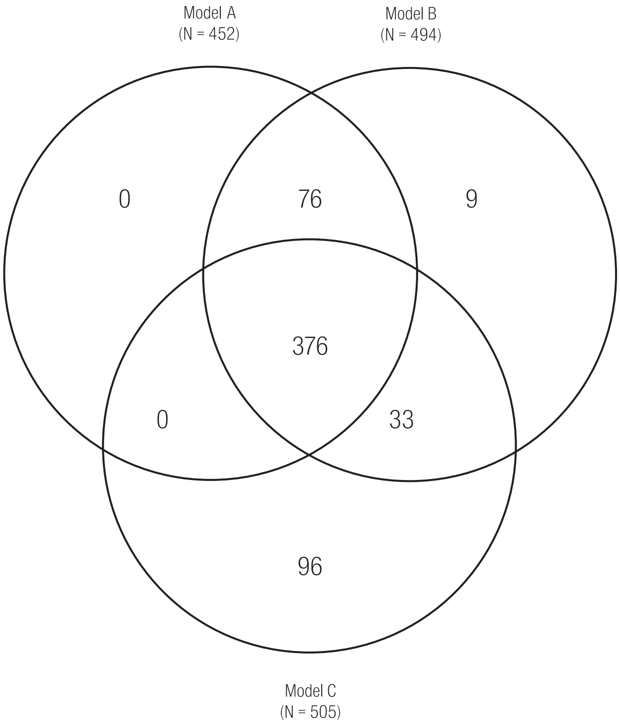

Fig. 3. Venn diagram presenting number of exposed children in three different scenarios of exposure

Table 2 shows the prevalence of respiratory disorders and symptoms according to the defined exposure categories. Comparisons involving Model A scenario revealed more diagnoses of asthma and rhinitis symptoms in children living close to the road. However, the differences were not statistically significant. Comparisons examined according to the Model B scenario (90th percentile as a cut-off of traffic counts) revealed findings that were similar to that obtained via Model A. Analysis performed according to Model C (90th percentile of traffic density) revealed that children living in the area with the highest traffic density had more diagnoses of respiratory disorders as well as respiratory symptoms than those living in the region with lower traffic density. Statistically significant differences were obtained for the occurrence of physician-diagnosed asthma.

Effect of exposure to traffic-related air pollution on respiratory outcomes was examined after adjustment for age, gender, parental education and history of respiratory and allergic diseases by means of logistic odds ratios (Table 3). Controlling for each and every confounder did not change conclusions provided by univariate analyses – the occurrence of physician-diagnosed asthma was associated with the exposure classified according to Model C (density of traffic).

In univariate and multivariate analyses, the effect of exposure on asthma appeared to be consistent and statistically significant only in relation to exposure index based on the density of traffic (Model C). The remaining effects were not statistically significant.

Table 2. Prevalence of respiratory health outcomes according to traffic metrics

Outcome	Studied children (N = 5733) (%)	Distance to heavy traffic road			Maximum traffic count within 100 m			Traffic density within 100 m		
		≤ 100 m (%)	> 100 m (%)	χ^2 p	> 90th percentile (%)	≤ 90th percentile (%)	χ^2 p	> 90th percentile (%)	≤ 90th percentile (%)	χ^2 p
Physician-diagnosed asthma	4.2	5.5	4.0	0.13	5.3	4.1	0.20	5.9	4.5	0.03
Allergic rhinitis	8.5	10.2	8.4	0.18	10.1	8.3	0.17	9.9	8.4	0.24
Rhinitis symptoms	26.0	27.9	25.8	0.34	27.9	25.8	0.30	28.5	25.7	0.17
Persistent cough	17.0	16.6	17.0	0.81	16.8	17.0	0.90	18.0	16.9	0.52
Chest wheeze	10.0	10.4	9.9	0.76	9.7	10.0	0.84	10.3	10.0	0.80
Seizures of dyspnea	8.3	7.3	8.4	0.42	7.1	8.4	0.30	8.7	8.3	0.73

Table 3. Relationship between traffic metrics and respiratory health outcomes

Outcome	Studied children (N = 5733) (n)	OR* (95% CI)		
		distance to the busy road (100 m)	maximum traffic count within 100 m	traffic density within 100 m
Physician-diagnosed asthma	238	1.47 (0.95–2.27)	1.40 (0.92–2.15)	1.60 (1.07–2.39)
Allergic rhinitis	487	1.28 (0.92–1.78)	1.28 (0.93–1.76)	1.24 (0.90–1.70)
Rhinitis symptoms	1 489	1.13 (0.91–1.41)	1.14 (0.92–1.40)	1.17 (0.95–1.44)
Persistent cough	975	0.98 (0.76–1.28)	1.00 (0.78–1.28)	1.09 (0.86–1.39)
Chest wheeze	572	1.09 (0.79–1.51)	1.01 (0.73–1.38)	1.08 (0.80–1.47)
Seizures of dyspnea	475	0.89 (0.61–1.29)	0.86 (0.60–1.24)	1.09 (0.79–1.52)

* Odds ratio adjusted for gender, age, financial family standing, maternal and paternal education, type of heating, exposure to environmental tobacco smoke at home, parental history of chronic respiratory disorders, and parental history of allergic disorders.

DISCUSSION

Results of our study suggest that the prevalence of asthma and allergic rhinitis in urban children is associated with exposure to traffic-related air pollution; however, the statistically significant effect concerns the diagnoses of asthma. The findings are consistent across three explored methods of expressing exposure to traffic-related air pollution, although the method involving estimation of traffic density in the residential area provided larger measures of associations compared to methods utilizing residential distance from the road (residential proximity to the road) or intensity of traffic on the road (maximum traffic count). An apparent trend in the magnitude of examined associations reflects an increasing reliability of exposure assessment and adds credibility to our findings. The study location being in the most industrialized and densely inhabited region of Poland allowed us to examine the respiratory effect of traffic pollution under specific environmental conditions. To our knowledge, this is the first study conducted in a highly polluted area, where pollutant concentrations (PM_{10}, SO_2) are higher than the relevant hygienic standards [12]. Thus, our study provides additional evidence that intense traffic may have respiratory effects even in an area with high levels of industrial and municipal air pollution.

Our findings are in line with evidence provided by other studies on respiratory effects of exposure to traffic-related air pollution. Many published papers focused on highways or freeways as a source of traffic air pollution. In California, occurrence of current asthma and bronchitis in the preceding 12 months in children was associated with proximity to highway in San Francisco Bay Area [7], also elevated rates of asthma in children living close to highways were observed in San Diego County [18]. Another study conducted in the same state showed an inverse linear relationship between lifetime history of asthma and residential distance from highway, and no associations were found when other major roads were taken into account [5]. However, the impact of exposure defined by residential proximity to major roads and not to highway was also reported by study performed in California [6].
There are some differences between United States and Europe in terms of traffic characteristic. The differences involve road infrastructure in and outside urban areas, diesel/gasoline ratio, or urban geography, but studies conducted in Europe usually provide evidence on the explored association that was similar to the results obtained in USA. In the southern region of the Netherlands, children living within 300m from a road with heavy truck traffic had more frequent respiratory disorders compared to control population [1,21]. Another study, conducted in the

same region, showed elevated rates of persistent cough, runny nose and physician-diagnosed asthma in children living within 100 m from a highway [9]. Studies performed in settings of different climatic conditions (England and Cyprus) found similar effects regarding the occurrence of respiratory disorders [8,22].

A number of studies utilized maximum traffic count near the residence as an indicator of exposure to traffic-related air pollution, and that index proved to be of value in explaining distribution of respiratory symptoms [4,7,9]. Our study results were in line with those findings; however, associations based on maximum traffic count did not reach the level of statistical significance. The only statistically significant association found was between asthma and index of exposure calculated by formula involving traffic density.

Our study had some limitations. First, a cross-sectional design was used, which has a limited power to explore environmental correlates of health outcomes. Respiratory disorders have multifactorial aetiology and a relatively weak contribution from traffic-related air pollution can be best investigated in a longitudinal manner, as shown by many recent studies [23–27]. Another limitation is related to the lack of specific measurements of the contribution of vehicle-related pollution to total air pollution in the region. A correlation of traffic-related air pollution with traffic intensity is generally recognised [3–5,23,28]. The levels of traffic-related air pollution in our study town are not very much different from the figures obtained in other urban areas in Europe, and the limited data available for our region seem to confirm that conjecture [29]. Moreover, in order to classify potential for exposure, objective measurements provided by the municipal environmental protection office were used, although the dataset only included selected roads.

Other possible source of bias in our research is the 68.5% response rate. Information on non-participant children (31.5%) and reasons of parents' refusal are unknown; moreover, we have no complete data on 3070 (27.4%) children and we have no possibility to assess relationship between health disorders and exposure to traffic-related air pollution. Therefore, we have decided to remove these records from the database.

Additionally, to reduce bias of our results that may be caused by differences in the environmental and socio-economic determinants between studied subjects and children living in the city centre, 2406 (21.5%) records were excluded from the analysis. Please note that children living in the city centre are at a higher risk of indoor pollution (ETS and coal heating-related pollution) and their socio-economic (financial and parental education) status is lower than that of the studied children. Both groups of determinants significantly affect the frequency of respiratory diseases and disorders [30].

The next question concerns the reliability of measurement of children health status by means of standardized respiratory questionnaire. Earlier published data from Poland suggest that ISAAC questionnaire is a proper tool for this assessment [31].

In spite of all those limitations, our study found some biologically plausible effects.

CONCLUSIONS

Results of our study suggest that respiratory diseases and symptoms in urban children living in industrial area of Upper Silesia (Poland) are associated with exposure to traffic-related air pollution. The magnitude of association is best seen in childhood asthma and becomes more apparent when more reliable indices of exposure are analysed.

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