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Airborne chemical pollution and children's asthma incidence rate in Minsk

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Key words:

Air pollution • Children's health • Asthma incidence rate

Summary

Introduction. *Asthma manifestations are closely connected with air pollution. Discovering interconnection between concentrations of air pollutants and asthma incidence rate among children provides information for developing effective measures to reduce air pollution and improve population health. Study purpose was to carry out hygienic analysis of the influence of atmospheric air quality on the incidence rate of bronchial asthma of children in Minsk in 2009-2018.*

Methods. *During 2019 retrospective health cohort study was conducted, data from stationary air quality monitoring posts were collected. Correlation analysis was conducted by determining the Pearson coefficient.*

Results. *Ten-year levels of asthma incidence rate had a moderate downward trend; the highest levels were registered among 5-9-year-old children. 74.7% of all cases of asthma were registered among children under 10 years: 33,61% among 1-4-year-old and 41.09% – among 5-9-year-old. Results of the study showed that concentrations of ammonia, particulate matter (dust/aerosol undifferentiated in composition) and lead in Minsk were characterized by downward trend, carbon oxide and nitrogen dioxide concentrations remained unstable, elevated levels of formaldehyde remained near highways with heavy traffic. Strong evidence was found for concentrations of particulate matter (dust/aerosol undifferentiated in composition) ($R = 0.76$-0.85, $p < 0.05$), lead ($R = 0.69$-0.97, $p < 0.05$), ammonia ($R = 0.64$-0.72, $p < 0.05$) nitrogen dioxide ($R = 0.63$-0.8, $p < 0.05$) and children's asthma incidence rate.*

Conclusions. *Obtained results indicate that particulate matter, lead, ammonia and nitrogen dioxide concentrations hesitation causes changes in children's asthma incidence levels. Not being the initial cause of the disease, they influence epidemic process and can be the target for preventive measures.*

Introduction

Air pollution is on the second place among reasons of economic losses of the gross domestic product of developing countries from mortality and morbidity associated with the negative impact of environmental factors at the population level [1] and the most important environmental risk factor for human health in the European Region [2]. Many studies prove that air pollution makes a significant contribution to the formation of disorders of the cardiovascular and respiratory systems, causing an increase in morbidity and mortality levels from diseases of the circulatory and respiratory systems [3-7]. Improving air quality can reduce the burden of diseases such as stroke, heart disease and lung cancer, as well as chronic and acute respiratory diseases, including asthma.

Asthma is one of the most common chronic diseases in the world. It is estimated that around 300 million people in the world currently have asthma [8]. It is a leading chronic illness among children and adolescents in the United States. Asthma is also one of the leading causes of school absenteeism [9].

Previous studies discovered that air pollution levels in big cities contribute greatly into developing asthma in children [10-13] and air pollution control can be one of the effective preventive measures to reduce asthma manifestations. Yet, studies on determination of air pollution effects on asthma manifestations in Minsk, 10th most populated city in Europe, hasn't been conducted.

Study objective was to explore the effect of air pollution on the levels of asthma incidence among children in Minsk. It would help in understanding the degree of environmental conditioning of children's asthma in Minsk, in comparing obtained results with global trends and determining the direction of preventive measures within the framework of reducing ambient air pollution.

Methods

Research design

The research design was retrospective health cohort study. Data were collected in 2019, study period – 2009-2018.

Data collection

Air quality data: system of monitoring air quality in Minsk is represented by 12 stationary and 40 route posts [14, 15]. In 2019 during the research was

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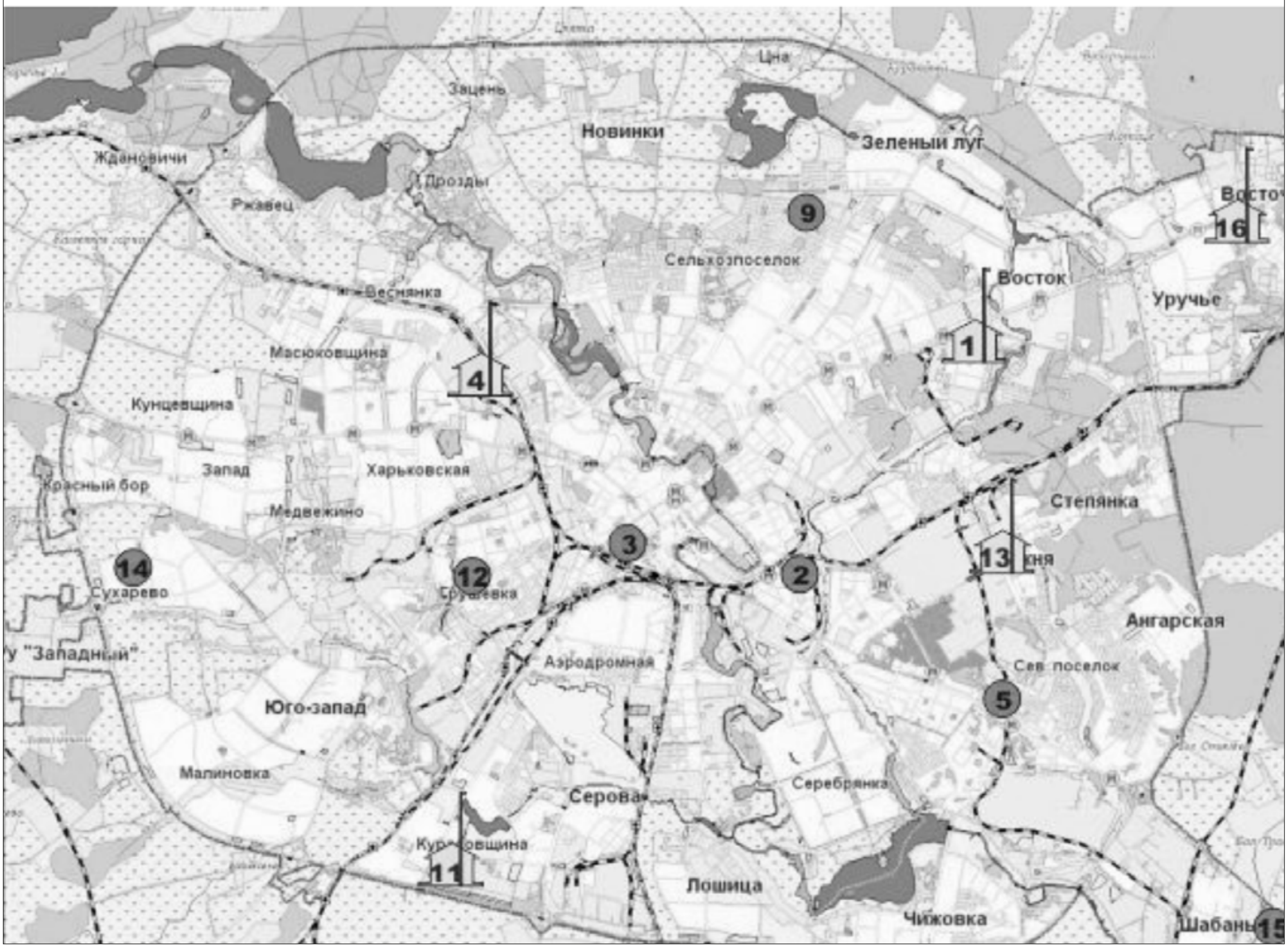
collected chemical annual concentration data from 12 stationary posts in 2009-2018. 12 stationary posts included 7 discrete monitoring posts and 5 automatic posts (Fig. 1). Monitoring technology at discrete posts included: air sampling by a chemical technician, their delivery to the laboratory and subsequent chemical analysis. Air samples were taken in absorption devices or aerosol filters within 20 minutes. Observations of pollutant concentrations were carried out daily 3 times a day (except Sundays and holidays). Automatic posts measured concentrations of pollutants automatically each hour. Annual concentrations were determined as average from several thousand measurements per year. Automatic posts controlled concentrations of particulate matter (fractions up to 10 microns), sulfur dioxide, nitrogen oxide, nitrogen dioxide, benzene, carbon oxide and ground-level ozone. Discrete posts measured concentrations of particulate matter (dust/aerosol undifferentiated in composition), carbon oxide, nitrogen dioxide, formaldehyde, ammonia, phenol, hydrogen sulfide, carbon disulfide. The inclusion criteria for pollutants in study were: the duration of pollutant concentration control in the atmospheric air at the post for 5 years or more; the percentage of samples with the result "below the sensitivity level of the method" less than 30%. In the study concentrations of following pollutants were analyzed in the atmosphere of Minsk: particulate matter (dust/aerosol undifferentiated in composition), nitrogen dioxide, ammonia, carbon oxide, formaldehyde and lead.

Health status data: Medical data concerning number of registered cases of asthma and asthmatic status (J45, J46) was collected from all Minsk children clinics (15 clinics), using annual governmental statistical reports. Population under study ranged from 311735 children in 2009 to 376,500 in 2018. Disease cases were structured by age groups: children under one year, 1-4 years, 5-9 years, 10-14 years and 15-17 years. Children under one year old were excluded from the study, as in 83% of the analyzed years 0 cases of asthma were registered in this group.

Population research

Retrospective study of asthma and asthmatic status incidence rate among children (0-17 years) living in Minsk was conducted in 2019, period of study included ten years (2009-2018). Asthma incidence rate was calculated to characterize morbidity as number of new cases of asthma or asthmatic status during a year divided by average children population during this year [16]

Fig. 1. Location of air monitoring quality posts in Minsk, Belarus, as of 2019 year. Circles mark discrete posts, home-formed figures – automatic posts. Posts numeration was saved and used in further study.



expressed in units per hundred thousand people. Obtained values of incidence rate were analyzed for 9 administrative districts of Minsk.

Statistical analysis

Descriptive statistical analysis was made for pollutant concentrations and incidence rate of asthma and asthmatic status: growth rate, average values, age-specific rates, long term trend (linear and polynomial) and prognosed levels were calculated. One sample Kolmogorov-Smirnov test showed normal distribution in asthma cases (0.47, $p = 0.979$) and in concentrations of particulate matter (dust/aerosol undifferentiated in composition) (0.9, $p = 0.698$), nitrogen dioxide (0.91, $p = 0.585$), ammonia (0.85, $p = 0.63$), carbon oxide (0.51, $p = 0.957$), formaldehyde (0.47, $p = 0.941$) and lead (0.6, $p = 0.835$). Correlation analysis was carried out by calculating Pearson's correlation coefficient between annual concentrations of main pollutants in the air and incidence rates of asthma and asthmatic status among children, the critical level of significance *p* when testing statistical hypotheses was taken equal to 0,05. T-test was used to determine differences between mean values.

Results

Air quality in Minsk

Concentrations of analyzed pollutants in ambient air in Minsk mostly didn't exceed national normative levels. Concentrations of nitrogen dioxide had slight downward trend in the atmosphere of the city, still maintained heterogeneity in different districts and average ten-year concentrations ranged from 26.9 $\mu g/m^3$ to 40.6 $\mu g/m^3$ (annual normative level in Belarus is 40 $\mu g/m^3$). Carbon oxide concentrations did not have expressed trend and varied diversely during analyzed period. Annual ten-year concentrations ranged from 320.53 $\mu g/m^3$ to 519.96 $\mu g/m^3$ (annual normative is 500 $\mu g/m^3$). (Fig. 2). Increased level of formaldehyde concentrations near highways with heavy traffic remained a characteristic feature of air pollution in Minsk. The maximum concentration of formaldehyde reached 12.3 $\mu g/m^3$ (annual normative is 3 $\mu g/m^3$) in 2014. Concentrations of particulate matter (dust/aerosol undifferentiated in composition), ammonia and lead were characterized by downward trend, the highest average ten-year concentration of ammonia was 14.9 $\mu g/m^3$. The maximum average ten-year concentration of lead reached 0.032 $\mu g/m^3$ (annual normative is 0.1 $\mu g/m^3$), maximum average five-year concentration of particulate matter (dust/aerosol undifferentiated in composition) reached 19.75 $\mu g/m^3$ (annual normative is 100 $\mu g/m^3$). Concentrations of the analyzed pollutants in administrative districts of Minsk did not have significant differences.

Children asthma incidence rate

The ten-year levels of incidence rate of asthma and asthmatic status among children in Minsk had a moderate downward trend, the growth rate was -1.51%, the highest levels were noted in 2011 and 2012 (182.9 and 188.7 per 100 thousand of the population, respectively). The minimum incidence rate was established in 2010 (128.9 per 100 thousand people). Regression analysis showed that model $y = -21,313x^2 + 55,881x + 172,49$ (polynomial trend, $R^2 = 0.9029$) was describing changes of incidence rate levels changes.

Analysis by age groups showed that 74.7% of all cases of asthma were registered among children under 10 years: 33,61% among 1-4-year-old children and 41.09% - among 5-9-year-old. Analysis of the dynamics of incidence rates showed an upward trend among children 15-17 years, a moderate tendency to decrease among children under 4 years and relatively stable trends among children 5-9 and 10-14 years. The highest level of incidence was found in 5-9 years old group (Fig. 3).

Over 10 years of observation, the maximum level of incidence rate of asthma was recorded in *Oktyabr'skiy* district (190.67 ± 7.6 per 100 thousand people), minimum – in *Partizanskiy* district (82.9 ± 7.21 per 100 thousand people). Analysis revealed a significant increase of incidence rate levels in *Oktyabr'skiy* ($t = 3.7$, $p = 0.02$) and *Frunzenskiy* ($t = 3.3$, $p = 0.03$) districts comparing with the average city levels. In the remaining districts, levels of asthma incidence rate did not exceed average city levels significantly.

Correlation analysis results

The correlation analysis, by means of the Pearson's correlation coefficient (R), highlighted strong positive and moderate positive correlation between asthma incidence rate among children of different age groups and concentrations of studied pollutants (Tab. I).

In 82.14% cases among discovered correlations were determined high positive correlations, in 17.86% - moderate positive. 43.48% of high positive correlation were noted for lead. In 35% of cases, a correlation was established for the age groups 1-4 years and 10-14 years, in 20% - for 5-9 years. Thus, the age group of children under 10 years old accounted for 55% of all correlations. When analyzing the distribution of the obtained correlations in the city districts, it was noted that more often than others, correlation between atmospheric air pollution and asthma incidence levels was found in *Zavodskoy* district (35,7% of all positive correlations).

Among polluting chemicals, whose concentration in the atmospheric air influenced asthma incidence levels among children, the most significant were: lead (39.3% of cases), nitrogen dioxide (21.4% of cases), and particulate matter (dust/aerosol undifferentiated in composition) (17.9% of cases).

Discussion

Results from this study showed that concentrations of analyzed pollutants mostly didn't exceed national standard levels. The most unfavorable situation was noted for formaldehyde, this is due to the fact that elevated levels of formaldehyde were formed due to oxidation of

Fig. 2. Annual concentrations of pollutants (μg/m3) at air monitoring quality posts in Minsk.

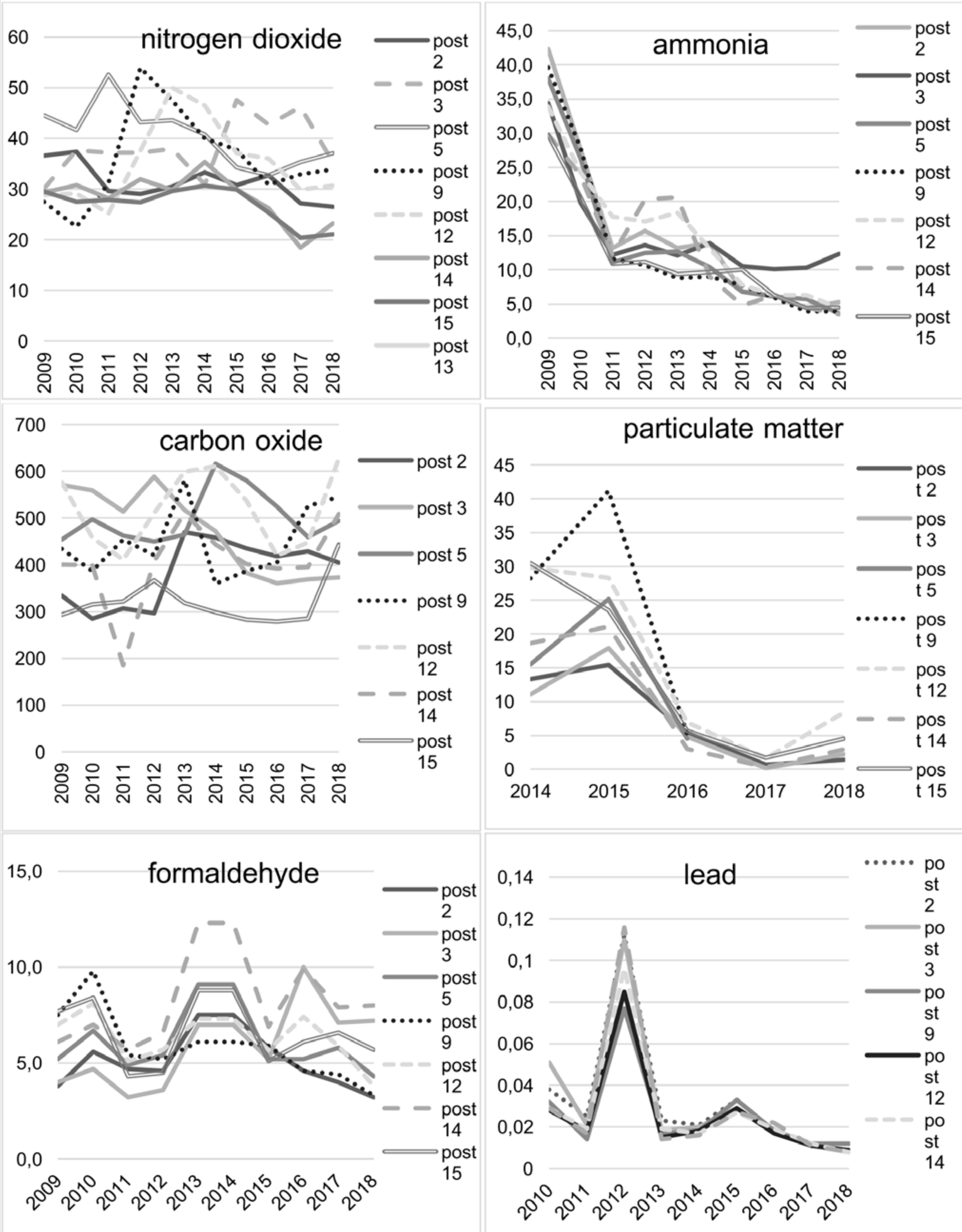
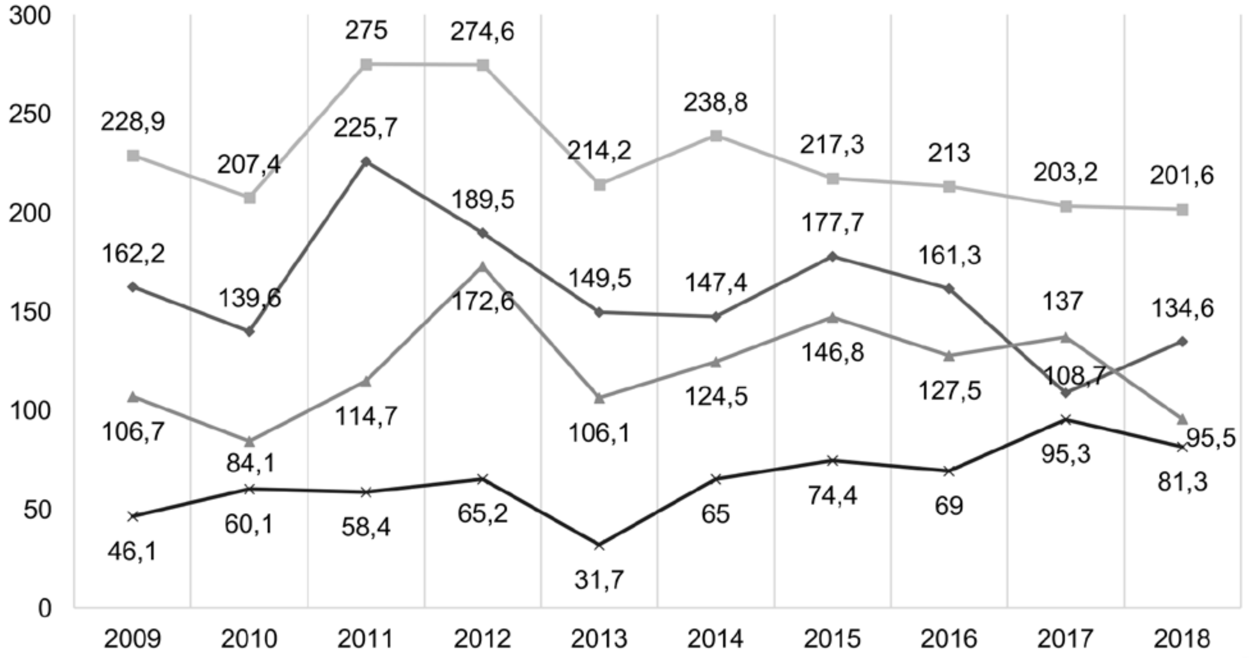


Fig. 3. Levels of asthma incidence rate (per hundred thousand people) in different age groups of children in Minsk in 2009-2018. Rhombus-marked line represents incidence rate for children under 4 years old, square-marked – 5-9 years old children, triangle-marked – 10-14 years old and cross-marked – 15-17 years.



Tab. I. Correlation analysis results between children asthma incidence rate and concentrations of pollutants, Minsk, 2009-2018.

District	Pollutant	Age group	R	p
Pervomayskiy	Nitrogen dioxide	5-9	0.683	0.043
		10-14	0.802	0.009
	Ammonia	1-4	0.722	0.018
		0-17	0.7	0.049
	Particulate matter (dust/aerosol undifferentiated in composition)	0-17	0.775	0.041
	Lead	5-9	0.705	0.034
		10-14	0.921	0.0009
		0-17	0.925	0.0009
Oktyabr'skiy	Carbon oxide	1-4	0.727	0.017
	Particulate matter (dust/aerosol undifferentiated in composition)	1-4	0.854	0.007
	Lead	10-14	0.909	0.001
		0-17	0.859	0.003
Moskovskiy	Lead	10-14	0.832	0.001
		0-17	0.685	0.042
Frunzenskiy	Carbon oxide	1-4	0.998	0.041
	Lead	15-17	0.93	0.0009
Zavodskoy	Nitrogen dioxide	1-4	0.721	0.019
		5-9	0.634	0.049
		0-17	0.721	0.049
	Ammonia	1-4	0.642	0.045
	Particulate matter (dust/aerosol undifferentiated in composition)	1-4	0.763	0.028
		5-9	0.846	0.016
		0-17	0.806	0.029
	Carbon oxide	15-17	0.72	0.019
	Lead	10-14	0.967	0.0009
		0-17	0.883	0.002
Sovetskiy	Nitrogen dioxide	10-14	0.66	0.035
	Lead	10-14	0.91	0.001

hydrocarbons [17, 18]. Therefore, formaldehyde content was formed not only by emissions of this substance, but also by the presence of other polluting chemicals and solar radiation. Formaldehyde can be irritating to the upper respiratory tract and eyes with inhalation exposure and play a significant role in the development of acute reflex reactions, including asthma among children [17, 19]. Concentrations of the analyzed pollutants in administrative districts of Minsk did not have significant differences, which is due to the fact that the layout of stationary posts is aimed at determining background concentrations in the city and excludes the influence of local especially large sources of atmospheric pollution.

Ten-year levels of asthma incidence rate in Minsk had a moderate downward trend for all children and moderate upward trend for 15-17-year-old children, the highest incidence levels were registered among 5-9-year-old children, absolute number prevailed in 1-4 and 5-9-year-old groups. Results of epidemiological analyses were similar with world trends: study of children asthma in USA showed that children who were 4 years-old or younger were less likely to have asthma, but the children in this age range with asthma were more likely to have asthma attacks (62.4%), emergency department or urgent care center visits (31.1%) and hospitalizations (10.4%) compared to older children who were 12 to 17 years-old [20]. Still global trend of asthma shows increase of asthma symptoms in children and adolescents, particularly in Low-Middle Income Countries [21]. The global epidemic of asthma that has been observed in both children and adults is still continuing especially in low to middle income countries, although some evidence suggests it has subsided in some high-income countries [22].

The correlation analysis highlighted positive correlation between asthma incidence rate and concentrations of particulate matter (dust/aerosol undifferentiated in composition), lead, ammonia and nitrogen dioxide. These interconnections have already been described in other studies. Study of Taiwan children health showed that lead exposure was associated with IgE and might increase the risk of asthma in children [23]. Ammonia exposure on children in literature shows controversial results on asthma morbidity. 13 months study in the Yakima Valley of Washington State showed no relationship between reported asthma symptoms and the weekly ammonia exposure estimated for the week before the interview date [24]. Still toxicological findings report that histopathologic examination of lung tissue after acute exposure to ammonia demonstrates acute pulmonary congestion and edema and desquamation of the bronchial epithelium [25, 26]. Professional exposure to ammonia in adults is associated with significant chronic irreversible and acute reversible decrements in the lungs' functional capacity [27]. Nitrogen dioxide and particulate matter (PM_{10} and $PM_{2.5}$) shows significant association with asthma exacerbations in children and adults [28]. In addition, many authors who have studied the effect of vehicle emissions on the asthma exacerbations in children, discovered a positive relationship between asthma incidence and the content of nitrogen, sulfur, and carbon oxides [11, 29, 30], $PM_{2.5}$ and black carbon [12], PM_{10} and nitrogen oxides [31-33].

We find results of this research important because of the fact that such studies in Minsk have not been carried out before. In this regard, on the one hand, the results obtained confirm the fact that the formation of asthma manifestations in Minsk is similar to global trends and is not strongly influenced by special local factors. On the other hand, the established fact of changes in the incidence of asthma in response to changes in the concentration of certain polluting chemicals in the atmosphere makes it possible to develop measures to reduce air pollution in such a way as not only to improve air quality, but also to reduce the incidence of asthma.

Possible limitations of our study may be connected with uneven location of air quality monitoring stationary posts, as well as with differences in the list of controlled pollutants. Thus, at the moment of research it did not seem possible to study the effect of the content of ultrafine particulate matter on the asthma incidence rate in whole Minsk, since the monitoring of ultrafine particles in Belarus has been carried out for less than 5 years and only at few posts. In addition, the study of the incidence rate by administrative district may somewhat distort the real picture, as some children may attend preschool and school institutions in other districts. However, children are less likely undergo intra-urban migration, they are more closely tied to the territory in which they live and do not experience the direct influence of professional factors, bad habits. In addition, due to the anatomical and physiological characteristics, children are more sensitive to the quality of their environment, increases the reliability of medical and statistical studies [34]. We suppose our incidence data was not subject to underdiagnosis [35], as Minsk city has highest in Belarus density and breadth of medical coverage for children.

Conclusions

In conclusion, findings suggest that Minsk outdoor air pollution in concentrations that mostly do not exceed national standards influences epidemic process of the development of asthma incidence and may be the goal for developing preventive measures. The results obtained by the authors were used by the sanitary service of Minsk in the development of preventive measures in a perspective five-year plan of Minsk development.

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Declarations of interest

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Authors contribution

ND: data analysis and interpretation, drafting the article
AH: conception or the work, revision of the article
LH: data analysis and interpretation, drafting the article
IS: conception or the work, revision of the article
DK: data collection, data analysis and interpretation
UU: data collection, data analysis and interpretation
NC: data collection, data analysis and interpretation
AV: data collection, data analysis and interpretation
EM: data collection, data analysis and interpretation
SE: conception or the work, revision of the article
NH: conception or the work, revision of the article

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