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Urban air pollution, climate and its impact on asthma morbidity

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ABSTRACT

Objective: To study the mechanism of formation of air quality and to determine the impact of the studied factors on asthma morbidity in Vladivostok.

Methods: The evaluation of air pollution in Vladivostok was done using long-term (2008–2012) monitoring data (temperature, humidity, atmospheric pressure, wind speed, *etc.*). The levels of suspended particulate matter, nitrogen and sulfur dioxide, carbon monoxide, ammonia, formaldehyde (mg/m^3) in six stationary observation posts were assessed. We studied the aerosol suspensions of solid particles, which were collected during snowfall from precipitation (snow) and air in 14 districts with different levels of anthropogenic impact. Melted snow was analyzed on laser granulometry. The impact of air pollution on the distribution of asthma morbidity was evaluated in various age groups by data of federal statistical observation obtained from 8 adults and 7 children municipal clinics in Vladivostok (2008–2012).

Results: The content of suspended particulate components of pollution remained more stable, due to the features of atmospheric circulation, rugged terrain and residential development. The nano- and micro-sized particles (0–50 μm), which can absorb highly toxic metals, prevail in dust aerosols. These respirable fractions of particles, even in small doses, can contribute to the increase in asthma morbidity in the city.

Conclusions: We determined that asthma morbidity depends from general air pollution (in the range of 18.3%). It was detected that the highest age-specific dependence is associated with the content of particulate matter, carbon monoxide and nitrogen dioxide in air.

1. Introduction

All of the environmental processes are the functional elements of the integrated systems (climate, topography, biota, *etc.*) and their interactions form the state of the air. Currently, the studies of air pollution have reached a new level due to the possibility of detecting new classes of toxicants: nano- and micro-sized particles. The microparticles have a higher toxicity and possess the ability to penetrate cell membranes, to circulate and accumulate in organs and tissues. They cause severe pathomorphological changes in the respiratory system, and their removal from body is very complicated [1,2]. Weather largely determines the conditions of accumulation and dispersion of pollutants in the air, significantly affecting the formation of air quality.

The polluted air of large cities is one of the causes of asthma morbidity. Air pollutants affect health differently, depending on age and individual features of response to the environment impact [3,4]. Therefore, the study of system “key” structures and positions responsible for the qualitative state of the city air will identify the contribution of individual pollutants in asthma morbidity in Vladivostok.

The aim of our work was to study the mechanism of formation of air quality and to determine the impact of the studied factors on asthma morbidity in Vladivostok.

2. Materials and methods

Vladivostok, large industrial city located in Primorsky region, Russia, was taken as an object of investigation. The

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industrial enterprises and intensive road traffic on low-quality roads significantly contribute to air pollution in Vladivostok. The rugged terrain of the city causes the unevenness of aerodynamic characteristics and high levels of air pollution, but the climatic features support air self-purification.

2.1. The evaluation of air pollution and climatic conditions in Vladivostok

The evaluation of air pollution in Vladivostok was done using long-term monitoring data on air quality (2008–2012) by Primorsky Department of Hydrometeorology and Environmental Monitoring and Center of Hygiene and Epidemiology of Primorsky Krai. The levels of suspended particulate matter, nitrogen and sulfur dioxide, carbon monoxide, ammonia, formaldehyde (mg/m^3) in six stationary observation posts were assessed [5].

We studied the aerosol suspensions of solid particles, which were collected from precipitation (snow) and air. Snow was collected during snowfall in 14 districts with different levels of anthropogenic impact. Melted snow was analyzed on laser particle sizer Analysette 22 NanoTec (Germany) to determine the size distribution and shape of the particles [6]. The laser granulometry method was used for the determination of the size of suspended particulate matter (PM), originated from the surface layer of the atmosphere, with preliminary aspiration of given air volume into liquid medium [7]. Suspended particles with various sizes were evaluated not only by size range, but also by the adsorption of toxic heavy metals [6].

We used monitoring data from Federal Service for Hydrometeorology and Environmental Monitoring (Primorsky Department of Hydrometeorology and Environmental Monitoring) to study the climatic conditions of the city. The actual parameters of temperature (T1), humidity (φ1), atmospheric pressure (P1), wind speed (V1), *etc*. were assessed. The previous (1–2 days) climatic data (T2, φ2, P2, V2, *etc*.) were also used for the characterization of the stability of the atmosphere, determining prolonged response from human respiratory system.

2.2. The assessment of asthma morbidity in Vladivostok

The impact of air pollution on the distribution of asthma morbidity was evaluated in various age groups by data of federal statistical observation (form No. 12) obtained from 8 adults and 7 children municipal clinics in Vladivostok (2008–2012). All the cases of acute illnesses and the first visit in year on the exacerbation of chronic disease (per 100 000 people) were included into the study. During the years 2008–2012, the large-scale construction of roads and bridges took place in the city, causing heavy air pollution by suspended components.

2.3. Statistical analysis

Statistica 10.0 (Statsoft) software was used for the mathematical and statistical methods of data processing (canonical analysis, multiple and rank correlation) and the probabilistic information-entropy analysis. Canonical analysis was used to determine systemic interconnections (R) between the groups of climatic parameters and anthropogenic pollutants. Multiple correlation was used to evaluate the correlation (r). Spearman rank correlation was used to identify air pollutants having the most impact on asthma morbidity in the city. Information-entropy analysis was used to determine the total quantitative contribution (%) of air pollutants in morbidity in conditions of informational uncertainty and randomness. The unconditional and conditional entropy were used as an analytical tool. The unconditional entropy indicated the level of informational uncertainty in variational series in morbidity. The conditional entropy allocated informational uncertainty from the perspective of air pollution impact (as a cause), arranging the entropy in the systemic relations “morbidity-air environment” [8,9]. Comparison of unconditional and conditional entropy allows to identify “useful information”, according to assessing the level of environmental dependence of morbidity. Since the data were of different dimensions and the number of components, the unit of account was taken as the rate of the relative entropy-the coefficient of redundancy (R%). The increase in the coefficient of redundancy indicated the decrease in entropy [9].

3. Results

Canonical analysis showed the intersystem relationships between the groups of climatic parameters and atmospheric pollutants ($R = 0.57$, $P = 0.0042$), which suggested a significant contribution of climatic conditions to the formation of air quality in the city. Pair correlations (r) between meteorological parameters and anthropogenic pollutants were calculated to select the climatic factors having the most impact on the level of air pollution (Table 1).

Table 1

The correlation (r) of climatic factors and indicators of anthropogenic air pollution in Vladivostok.

Climatic factors	Indicators of anthropogenic air pollution (mg/m^3)			
	Nitric oxide	Nitrogen dioxide	Particulate matter	Formaldehyde
Season (winter, spring, summer, autumn)		0.25^b	0.20^a	0.21^b
Actual atmospheric effects		0.27^b		
Actual humidity, φ1 (%)		0.25^b	0.17^a	0.16^a
Actual temperature, T1 (°C)			0.23^b	0.24^b
Previous temperature, T2 (°C)				0.24^b
Actual dew point, t_p1 (°C)			0.23^b	0.23^b
Change in atmospheric pressure, (P2−P1) (mm Hg)	0.26^b	0.28^b		
Previous wind speed, V2 (m/s)				0.21^b
Change in wind speed, (V2−V1) (m/s)	0.20^b	0.25^b		0.31^b
Wind direction, wd1 (compass points)			0.18^a	0.24^b

Statistically significant differences between groups: ^{a} for $P \leq 0.05$, ^{b} for $P \leq 0.01$.