The Influence of Environmental Factors on Population Mortality of Krasnoyarsk City

Daria A. Chernykh[1,2], Olga V. Taseiko[1,2], Ulyana S. Ivanova[1,3]

[1] Institute of Computational Technologies SB RAS, Krasnoyarsk Branch office, Krasnoyarsk, Russian Federation, krasn@ict.nsc.ru
[2] Reshetnev Siberian State University of Science and Technology, Krasnoyarsk, Russian Federation, info@sibsau.ru
[3] Siberian Federal University, Krasnoyarsk, Russian Federation, office@sfu-kras.ru

Abstract. The analysis of environmental factors influence on the mortality rate of the Krasnoyarsk's population is executed with using the generalized linear model with Poisson regression. The study's object was the population mortality rates for Krasnoyarsk city in the age from 60 to 74 years old for the period from 2010 to 2014. The purpose of the study is to assess the degree of common influence of climatic and environmental factors on the population mortality rates for Krasnoyarsk city.

Keywords. air quality; climatic parameters; generalized linear model with Poisson regression; population mortality.

1 Introduction

The growth of urban areas has allowed expanding access to many facilities, such as transport, energy, education, water supply, etc. As a result, automobile and industrial growth, combined with adverse weather conditions, have caused several worldwide episodes of excessive air pollution with loss of life and damage to health. An example is the well-known disaster in the American city of Donor, Pennsylvania in 1948, in which 20 people died and more than 5,910 people fell ill [1]. Since then, increasing attention has been paid to studying the effects of air pollution on public health. Many epidemiological studies have been carried out that have shown that air pollution affects human health, especially for respiratory and cardiovascular diseases, even if the concentration levels of pollutants are below standard levels of air quality [2-7].

With the interaction of anthropogenic and natural factors, the risks of sustainable development of territorial entities increase, while trends that urbanize (transform) the natural environment are actively manifested, creating new types of natural and man-made threats. Estimates of the pace and level of sustainable development require the use of a methodology for accounting for various factors of individual and collective risks [8-11].

The climate of the Krasnoyarsk region is characterized by the presence of high temperatures in the summer and extremely low in the winter and refers mainly to the sharply continental type. In connection with such climatic features, as well as the presence of industrial agglomerations for the Krasnoyarsk region, an analysis of the synergistic influence of climatic parameters and environmental factors on mortality rates is relevant. To solve this problem, it becomes necessary to develop a methodology for assessing the risks of multifactorial effects on mortality, using multivariate statistical models that take into account the characteristics of the region and the structure of the population, as well as developing measures to protect the population from environmental factors.

Assessing the impact of air pollution on human health is complex due to the fact that some characteristics of the population (age, genetics, social conditions, etc.) affect the body's response to polluted air. For example, it was shown that a higher concentration of air pollution increases the number of respiratory diseases in the elderly and children, while children are more susceptible, since they need twice as much air inhaled by adults [2-3]. While for older people, a weaker immune and respiratory systems have a more significant effect, as well as the fact that they have been exposed to significant air pollution throughout their lives. Another important factor is genetics. Studies have shown that people with chronic illnesses or allergies, such as bronchitis and asthma, are more sensitive to air pollution.

The aim of the study was to assess the degree of joint influence of climatic parameters and environmental factors on the mortality of the population of Krasnoyarsk.

2 Materials and methods

The object of the study was the mortality of residents of Krasnoyarsk in the age group of 60 to 74 years from the most common diseases characterized by sensitivity to climatic factors for the period from 2010 to 2014:

- ischaemic heart diseases (I20 – I25);
- cerebrovascular diseases (I60 – I69);
- diseases of the respiratory system (J00 – J22, J30, J40 – J45);
- external causes of mortality (V01 – Y98).

To solve this problem, a database of mortality indicators was used, provided by the Territorial Authority of the Federal State Statistics Service for the Krasnoyarsk Region. Daily mortality in Krasnoyarsk was studied for 5 years (from January 1, 2010 to December 31, 2014).

The climatic characteristics were identified using dispersion analysis methods of independent samples to assess the effect of short (discrete) weather episodes – heat and cold waves and sudden changes in temperature during the day on mortality.

The dependence of mortality on air pollution and climatic factors is recommended to be studied using the Poisson regression model (1-2) [12]

$$ln(\mu_t) = \beta_0 + \beta_1 \cdot X_{1,t-L} + \dots + \beta_k \cdot X_{k,t-L} + \beta_{k+1} \quad (1)$$
$$\mu_t = e^{\beta_0} \cdot e^{\beta_1 \cdot X_{1,t-L}} \cdot \ldots \cdot e^{\beta_k \cdot X_{k,t-L}} \cdot e^{\beta_k} \quad (2)$$

where μ_t is mortality;
$x_{1,t} \dots x_{k,t}$ – the explanatory variables;
L – effects of time-lag;
$\beta_1 \dots \beta_{k+1}$ – the regression coefficients;
β_0 represents the value of μ_t when all the explanatory variables are null (free member).

The model provides for the calculation of the coefficient for various lags (time delay of the body's response to negative effects) from zero to 14 days.

To estimate the coefficient of the proposed Poisson model, the average daily concentrations of pollutants and meteorological parameters for the period from 2010 to 2014 were also used:

1. The pollutant's concentration:
- nitrogen dioxide;
- formaldehyde;
- particulate matter. Data on the daily concentration of pollutants in the city of Krasnoyarsk were provided by the Federal Service for Hydrometeorology and Environmental Monitoring of Russia.

2. Meteorological indicators:
- air temperature;
- relative humidity;
- extreme temperature change during the day;
- temperature waves. To assess the meteorological parameters, we used data from meteorological station, which is the background for Krasnoyarsk city [13].

3 The results of the study

Table 1 shows the parameters of the Poisson regression model for assessing the influence of environmental factors on mortality from respiratory diseases among women.

Table 1. The calculated coefficients of Poisson regression model for women, respiratory diseases.

Explanatory variables	Regression coefficients. β_i	Lag. days	Standard error	p-value
Free member	-7.6	-	5.5	0.2*
Formaldehyde (*F*)	77.2	12	33.7	0.022
Air temperature (*Temp*)	-0.4	2	0.1	0.012
	-0.3	12	0.1	0.023
Extreme temperature change during the day (*Diff*)	0.1	1	0.06	0.025
	0.1	12	0.05	0.017
Relative humidity (*Hum*)	0.1	11	0.04	0.024
Temperature waves (*W*)	0.3	9	0.1	0.035

* – Dependence is not statistically significant (p > 0.05).

For the obtained parameters. the Poisson regression model will take the form (3)

$$\ln(\mu_t) = -7.6 + 77.2 \cdot F_{t-12} - 0.4 \cdot Temp_{t-2} - 0.3 \cdot Temp_{t-12} + 0.1 \cdot Diff_{t-1} + 0.1 \cdot Diff_{t-12} - 0.1 \cdot Hum_{t-11} + 0.3 \cdot W_{t-9} \quad (3)$$

where F – formaldehyde concentration;

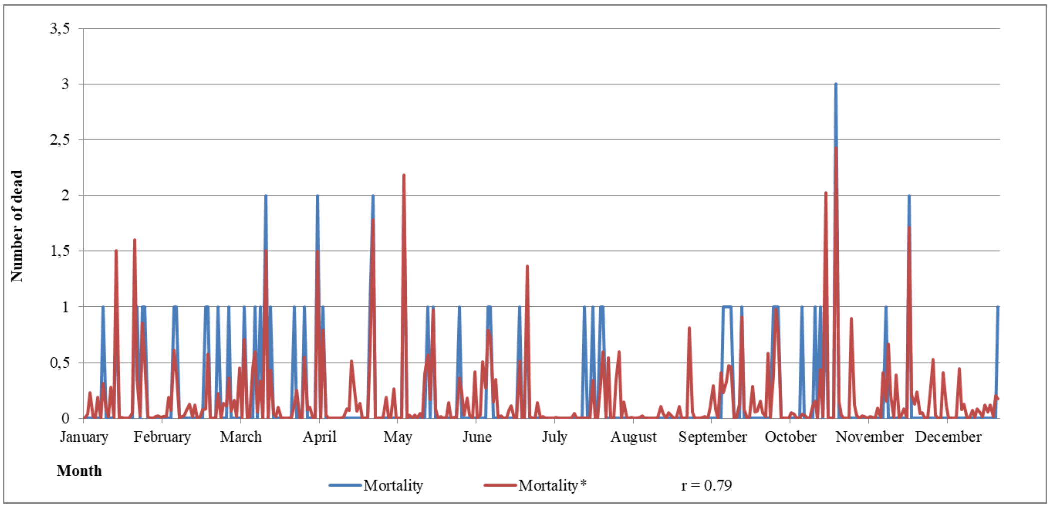
$Temp$ – air temperature;

$Diff$ – extreme temperature change during the day;

Hum – relative humidity;

W – temperature waves.

The calculated indicator describes well the actual mortality from respiratory diseases among women with a correlation coefficient of 0.79.



Actual and estimated mortality from respiratory diseases for women.

A summary analysis of the coefficients of all implementations of multidimensional models obtained according to formulas (1-2) is presented in Table 2. Empty cells in the table mean that the factors of influence indicated in the rows do not significantly affect mortality from the corresponding causes indicated in the columns.

Table 2. The estimated coefficients of the model prediction of mortality.

Explanatory variables	Sex	Ischaemic heart diseases	Cerebrovascular diseases	Diseases of the respiratory system	External causes of mortality
Correlation	W	0.69	0.65	0.79	0.72
	M	0.6	0.62	0.6	0.68
Regression coefficients. β_i / Lag. L					
Nitrogen dioxide concentration	W	16.5 L=5	22.9 L=15		63.2 L=14
	M	10.9 L=5	16.7 L=13	26.3	20.3 L=5
Formaldehyde concentration	W			77.2 L=12	72 L=9
	M		26.3 L=4		
Particulate matter	W	1.2 L=5	1.9 L=8		5 L=8
	M	1.1 L=15	1.7 L=5		
Air temperature	W				
	M				
Relative humidity	W	0.02 L=6		0.1 L=11	0.07 L=5
	M				0.03 L=7
Extreme temperature	W			0.1 L=1	0.1 L=1

change during the day	M			0.04 L=5	0.04 L=14
Temperature waves	W	0.06 L=2		0.3 L=9	0.3 L=7
	M				

When analyzing the obtained models, the following results were revealed (table 2):

1. The greatest contribution to the mortality of the population is made by air pollution, which is reflected in all the models obtained, regardless of the causes of mortality;
2. When analyzing gender-disaggregated models, it was revealed that women are more exposed to environmental factors;
3. Population dying from external causes is most affected by environmental factors. Least from cerebrovascular diseases;
4. With regard to the degree of closeness of the relationship between actual and calculated mortality, the highest correlation coefficients are observed from external causes and from respiratory diseases;
5. An analysis of the distribution of lags shows that most of the negative effects in men manifest up to six days after exposure to adverse factors, while in women negative effects for health appear up to ten days.

Further development of this approach will be associated with the introduction of adjustments to the model for seasonal, weekly or daily trends and clarification of the methods for introducing such climatic factors as heat waves and temperature contrasts into the model.

The reported study was funded by Russian Foundation for Basic Research, Government of Krasnoyarsk Territory, Krasnoyarsk Regional Fund of Science, to the research project No 19-413-240013 «Risk assessment methodology caused by environmental factors on population health and mortality in industrial agglomerations».

References

[1] Lipfert F.W. A critical review of studies of the association between demands for hospital services and air pollution // Environmental Health Perspectives Supplements. 1993. Vol. 101, Suppl. 2. P. 229-268.

[2] Braga A.L.F., Conceição G.M.S., Pereira L.A.A et al. Air pollution and pediatric respiratory hospital admissions in Sao Paulo, Brazil // Journal of Occupational and Environmental Medicine. 1999. Vol. 1. P. 95-102.

[3] Braga A.L.F., Saldiva P.H.N., Pereira L.A.A. et al. Health effects of air pollution exposure on children and adolescents in Sao Paulo, Brazil // Pediatric Pulmonology. 2001. Vol. 31. P. 106-113.

[4] Burnett R.T., Cakmak S., Brook J.R. The effect of the urban ambient air pollution mix on daily mortality rates in 11 Canadian cities // Canadian Journal of Public Health. 1998. Vol. 89. P. 152-156.

[5] Ibald-Mulli A., Timonen K.L., Peters A. et al. Effects of particulate air pollution on blood pressure and heart rate in subjects with cardiovascular disease: A multicenter approach // Environmental Health Perspectives. 2004. Vol. 112, No. 3. P. 369-377.

[6] Peng R.D., Dominici F., Louis T.A. Model choice in time series studies of air pollution and mortality // Journal of the Royal Statistical Society Series A. 2006. Vol. 169. P. 179-203.

[7] Pope III C.A., Burnett R.T., Thun M.J. et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association. 2002. Vol. 287, No. i9. P. 1132-1142.

[8] Safety of Russia. Legal, socio-economic, scientific and technical aspects. Regional safety issues. Krasnoyarsk region, 2001. MGF "Knowledge", Moscow, 576.

[9] Vinokurov Yu.I., Lepikhin A.M., Moskvichev V.V., Chernyakova N.A. Geoinformation technologies and mathematical models for monitoring and managing environmental and socio-economic systems. Barnaul: IVEP SB RAS. Five Plus, 2011. 250 p.

[10] Levkevich V.E., Lepikhin A.M., Moskvichev V.V., Nikitenko P.G. et al. Security and risks of sustainable development of territories. Krasnoyarsk: Siberian Federal University, 2014. 224 p.

[11] Akimov V.A., Bykov A.A., Shevchenko A.V., Strelko S.V. The development of scientific and methodological foundations of public administration using strategic risk indicators, including emergency risks (for example, the Ulyanovsk region) // Civil protection strategy: problems and research. 2013. Vol. 3, No. 2. P. 736-780.

[12] MP 2.1.10.0057-12.2.1.10. The health status of the population in connection with the state of the environment and living conditions of the population. Assessment of risk and damage from climate change affecting the increase in morbidity and mortality in high-risk population groups (approved on January 17, 2012). 36 p.

[13] All-Russian Research Institute of Hydrometeorological Information – World Data Center. http://meteo.ru/ (Date of access 11.11.2016).