



Risks for Population Health from Atmospheric Air Pollution in the City of Kazan

Nataliya V. Stepanova* and Suryana F. Fomina

Kazan Federal University, Institute of Fundamental Medicine and Biology, 74 K. Marx Street, 420008, Russia

* Correspondence: stepmed@mail.ru; Tel.: +7-917-399-9907

† Presented at the 1st International Electronic Conference on Environmental Health Sciences, 15 November–7 December 2018; Available online: <https://iecehs-1.sciforum.net/>.

Published: 14 November 2018

Abstract: The assessment of non-carcinogenic risk for the population health from chemicals coming with exhaust gases of motor transport citywide and in certain districts of the city of Kazan was performed. The calculation was carried out according to the results of the laboratory and instrumental tests carried out by FBHI “Center of Hygiene and Epidemiology in the Republic of Tatarstan” for the period from 2010 to 2016. The general toxic effect on the organs of the respiratory system from (42.5 to 62.0%) in the city and districts is due to exposure to the total fraction of TSP, PM₁₀ and PM_{2.5}. Population risk of the total TSP impact made 1244 cases of additional deaths per year among the city population, apart from external causes. In Vakhitovsky and Sovetsky districts, this index for the whole population made 86 and 281 per year correspondingly. The absence of data on the age-specific death rate in the districts did not allow calculating the given indices for certain age groups. Damage associated with total morbidity of asthma among the cumulative city population caused by the exposure to PM₁₀ made 486 cases in adults and 67 cases in children per year. Damage from the exposure to PM_{2.5} made 332 additional deaths from all causes (14.6%); 1727 from cardiovascular diseases (4.5%); 18 - from respiratory diseases (6.0%). Currently, the assessment of mortality and diseases caused by the air pollution is the starting point for development or correction of regulatory actions in the field of the environmental and the population health protection at the regional levels.

Keywords: atmospheric air; vehicles; monitoring; public health risk

1. Introduction

Numerous epidemiological studies carried out during the last decades indicate adverse health effects from exposure to atmospheric air pollution [1-3]. A new WHO air quality model confirms that 92% of the world's population lives in places where air quality levels exceed WHO limits. Suspended substances (solids - PM_{2.5} and PM₁₀), deeply penetrating and depositing in different parts of the airways, having various sources and composition, and causing cardiovascular diseases, including stroke, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, pneumonia in particular, have serious consequences for human health [1,4-10]. New studies include a large volume of evidence, which are at present under consideration of WHO in REVIHAAP (Review of evidence on health aspects of the atmospheric air pollution) and HRAPIE (health risks from air pollution in Europe) Projects, and confirm that the external air pollution is an important health risk factor [1,12,13]. Monitoring of concentrations and decrease of the air pollution with fine suspended particulates PM_{2.5} and PM₁₀ in large industrial cities, to which the city of Kazan refers, is a vital task of social and hygienic monitoring and management of population health risks.

Aim – to assess the population health risk from chemicals coming with atmospheric air in the city and in two (Sovetsky and Vakhitovsky) districts of the city of Kazan with account of

recommendations on the use of concentration – response functions concerning mortality and morbidity associated with long-term exposure of particulate matter (PM).

2. Materials and Methods

Pollution characteristics of the city of Kazan in Vakhitovsky and Sovetsky city districts is given according to the results of the laboratory and instrumental tests carried out by FBHI “Center of Hygiene and Epidemiology in the Republic of Tatarstan” at the monitoring points for the period from 2010 to 2016. Exposure was assessed on the basis of measured average annual concentrations on the territory all over the city and two districts. Annual data on the population size in the city of Kazan and mortality from various causes and age groups (selected in accordance with WHO [12], and coded in accordance with the 10-th International Classification of Diseases (ICD)) were obtained from Annual Statistical Bulletin “Natural population migration of the urban and municipal districts of the Republic of Tatarstan” for the period of 2010-2016. The target population included all permanent residents living in the city of Kazan and two districts distinguished by location of industrial enterprises, plants, and the vehicle density. Vakhitovsky district - the central part of the city, with total number of standard residential population of about 89.0 thousand people, and Sovetsky district located in the north-east and east parts with population of more than 311.0 thousand people were selected for study. The calculation of risk of developing non-carcinogenic effects from pollutants contained in the atmospheric air was carried out in accordance with Guidelines for assessing the population health risk on exposure to chemicals polluting the environment (Manual R 2.1.10.1920-04) [13]. To identify the number of attribute-based outcomes resulting from the analyzed impact of TSP, PM₁₀ and PM_{2.5}, the concentration-response function (CRF) expressed in terms of the value of relative risk (OR) per 10 µg/m³ and the frequency of analyzed health problems per 1000 population were used [12-14].

3. Results and Discussion.

Analysis of the carried out laboratory and instrumental studies of atmospheric air in the city of Kazan showed that 7 - 13 pollutants are controlled in given points. Most of them (nitrogen dioxide, sulphur dioxide, carbon oxide, suspended particulates, and formaldehyde) are on the list of priority substances contained in the atmospheric air of the cities/towns of the Russian Federation and the inventory list of toxic substances' emission of the US Environmental Protection Agency (US EPA). For the period under study, the contribution of the automobile transport to atmospheric pollution in Kazan remained high and made 69.4% - 73.8% of the total gross emissions. The atmospheric air pollution level for the period of 2010-2014 in the city of Kazan was characterized as “high”: SI (standard index) 13.1 – 13.6; API (a Complex Air Pollution Index taking into account several impurities) 7-13. From the year of 2014, after introduction of amendment No.11 into Hygienic Norms GN 2.1.6.1338-03 “Maximum allowable concentrations (MAC) of pollutants in atmospheric air of populated areas” and the introduction of new sanitary and hygienic standards for concentrations of formaldehyde and phenol, the pollution level in the city was determined as “low”, being underestimated by a factor of more than 3 and 2 correspondingly in comparison with the former level. The threshold concentration values of TSP (0.01 mg/m³), PM₁₀ (0.0075 mg/m³) and PM_{2.5} (0.0035 mg/m³) were used as the background exposure levels (Table 1).

Table 1. Results of assessing non-carcinogenic risk from chemicals polluting atmospheric air for the population health in certain districts of the city of Kazan.

Substances	RfC mg/m ³	M ^a , mg/m ³	HQ	%	M ^a , mg/m ³	HQ	%	M ^a , mg/m ³	HQ	%	
Points	Kazan				Vakhitovsky district			Sovetsky district			
TSP	0.075	0.148	1.98	17.09	0.15	2	14.18	0.153	2.04	17.29	
Sulphur Dioxide	0.05	0.001	0.02	0.17	0	0	0.00	0	0	0,00	
Carbon Oxide	3	1.771	0.59	5.11	3.097	1.032	7.32	3.874	0	10.94	
Nitrogen Dioxide	0.04	0.070	1.74	15.04	0.09	2.25	15.96	0.105	1.29	22.25	
Nitrogen Oxide	0.06	0.024	0.39	3.41	0	0	0		2.63	0	
Hydrogen Sulphide	0.002	0.001	0.57	4.91	0	0	0	0	0	0	
Phenol	0.006	0.001	0.19	1.66	0	0	0	0	0	0	
Ammonia	0.1	0.022	0.22	1.93	0	0	0	0	0	0	
Benz(a)pyrene	1	1.982	1.98	17.14	0	0	0		0	0	
Formaldehyde	0.003	0.008	2.63	22.75	0.002	0.667	4.73	0	0	0,00	
PM ₁₀	0.05	0.081	1.63	12.99	0.098	1.96	13.90	0.041	0.82	6.95	
PM _{2.5}	0.015	0.038	2.57	20.47	0.052	3.467	24.59	0.025	1.67	14.12	
Carbon (soot)	0.05	0	0	0	0.136	2.72	19.29	0.168	3.36	28.47	
HI ^b			14,51			14,09			11,8		

^a Average concentrations; ^b HI the total hazard index with account of TSP, PM₁₀ and PM_{2.5} fractions.

Analysis of HI in the city and the city districts showed that they are within the same limits and correspond to the extremely high risk level (HI more than 10). According to the assessment results, the total impact of suspended particulates of PM_{2.5}, PM₁₀ and total dust (TSP) contribute most to the total value of non-carcinogenic risk in the city of Kazan (42.5%) and the districts under study (in Vakhitovsky district – 52.7%, in Sovetsky district – 59.9%). The priority contribution in the city of Kazan is determined by nitrogen dioxide and formaldehyde (15-22.7%), and in Vakhitovsky and Sovetsky districts – by nitrogen dioxide and carbon (soot), 16.0% - 22.25% and 19.3% and 28.5% correspondingly. Organs of the respiratory system (HI = 11.93; 13.06 and 10.51) are highly vulnerable to the risk of developing general toxic effects on chronic exposure to chemicals coming from atmospheric air in the city and districts due to exposure to TSP total fraction (from 42.5 to 62.0%).

According to WHO and depending upon availability of data in calculations we used the recommended values of relative risk (RR) for additional number of health outcomes and "concentration – response" functions (CRF) per 10 µg/m³ associated with exposure to PM₁₀ and PM_{2.5}. Population risk of the total suspended particulates' impact made 1244 cases of additional deaths per year among the city population, apart from external causes. The number of additional deaths for the whole population in different age groups of the population in the city of Kazan made from 7.8 to 1043 cases in the retirement-age adults per year (Table 2).

Table 2. Additional number of outcomes per year from the effect of suspended particulates in the city of Kazan.

Receptor Point (of the District)	Health Impacts	ICD-10	Population Groups	RR per 10 µg/m ³	The Frequency of Responses
TSP					
Kazan	All-cause mortality		All		1244
PM ₁₀					
Kazan	Mortality from CVD	J00-99	All	1,014	574
Kazan	Mortality from RD	J00-99	All	1,034	53
Kazan	All-cause mortality	A00 – R99	All	1,0074	565
Kazan	Prevalence of bronchitis	J40-43	0-14	1,08	122
	Prevalence of bronchitis	J40-43	18+	1,117	9919
Vakhitovsky district	Prevalence of bronchitis	J40-43	0-14	1,08	15

Sovetsky district		J ₄₀₋₄₃	0-14	1,08	9
Kazan		J ₄₅₋₄₆	0-14	1,0512	486
Kazan	health encounters for asthma	J ₄₅₋₄₆	18+	1,004	67
Vakhitovsky district		J ₄₅₋₄₆	0-14	1,0512	3398
Sovetsky district		J ₄₅₋₄₆	0-14	1,0512	7156
PM _{2.5}					
Kazan	Mortality from CVD	J ₀₀₋₉₉	All	1,02	1727
Kazan	Mortality from RD	J ₀₀₋₉₉	All	1,022	18
Kazan	All-cause mortality	A _{00 – R₉₉}	All	1,06	332

In Vakhitovsky and Sovetsky districts, this index for the whole population made 86 and 281 per year correspondingly. The absence of data on the age-specific death rate in the districts did not allow calculating the given indices for certain age groups. Damage associated with total morbidity of asthma among the cumulative city population caused by the exposure to PM₁₀ made 486 cases in adults and 67 cases in children per year. Possible additional number of health encounters for chronic bronchitis associated with exposure to PM₁₀ among the child population in the city of Kazan made 122 cases, and among the adults - 9919 cases per year. The possible damage on exposure to PM_{2.5} made additionally 15 cases of chronic bronchitis per year in Vakhitovsky district and 9 cases in Sovetsky district; 565 additional deaths from all causes (4.8%) in the city of Kazan; 574 - from cardiovascular diseases (7.9 %); 53 - from respiratory diseases (17.7%). Damage from the exposure to PM_{2.5} made 332 additional deaths from all causes (14.6%); 1727 from cardiovascular diseases (4.5%); 18 - from respiratory diseases (6.0%).

The major limitation of our study was in absence of the age-specific data on mortality in the city districts. However, it allowed assessing the possible damage associated with total morbidity of chronic bronchitis and asthma in the class of "Respiratory diseases" (J00-J99), which is of great importance for the child population aged from 0 to 14 years old (Table 2). Analysis of epidemiological data in the city of Kazan and the city districts for the last ten years indicates that RD rank first in the structure of child morbidity (more than 50%) and are environmental diseases. [15-20]. The HRAPIE report indicates that generalization of the recommended approaches to other regions of the globe or individual countries, or to particular mixtures at the local level, may be not appropriate. Specifically, risk estimates for certain health outcomes exhibit more uncertainty. It bears noting that the background national data on all-cause mortality have greater precision than the cause-specific data. The air pollution from exposure to PM_{2.5} caused 14.6% of total mortality or more than 1727 cases per year, and from exposure to PM₁₀ - 4.8% or 565 cases per year, correspondingly, for the population of the city of Kazan. The present study provides strong evidence that respiratory disease mortality (17.7% or 53 additional cases) and cardiovascular diseases (7.9% or 574 additional cases) is significantly associated with PM₁₀ in the city of Kazan.

4. Conclusions

Our results enhance the existing evidence of the fact that atmospheric air pollution is a significant environmental risk factor for mortality and respiratory diseases [21-23]. A monitoring system available in large cities, undercount of the atmospheric air pollutants prevents from correct assessment of the potential risk and actual damage for the population health. Due to limited sample volume and the aim of our study further studies in the city of Kazan with account of exposure to NO₂ and black carbon, the health impacts of which and untimely mortality can be used as the major indicator for PM, which are formed in road traffic, are required. Currently, the assessment of morbidity and diseases caused by the air pollution is the starting point for development or correction of regulatory actions in the field of the environmental and the population health protection at the regional levels. The quantitative assessment of the air pollution impact on the population health became the aim of the choice of policy option or options carried out for comparison of benefits from measures to decrease the ecological burden of pollution and the costs of their implementation.

Acknowledgments: This work was funded by the subsidy allocated to Kazan Federal University for the state assignment in the sphere of scientific activities 19.9777.2017/8.9

Conflicts of Interest: The authors declare no conflict of interest

References

1. European Environment Agency report 2015 Air Quality in Europe – 2015 (Denmark).
2. Rakhmanin, Y.A.; Novikov, S.M.; Avaliani, S.L.; Sinitsyna, O.O.; Shashina, T.A. Actual problems of environmental factors risk assessment on human health and ways to improve it. *Health Risk Analysis*. **2015**, *2*, 4-11.
3. Review of evidence on health aspects of air pollution—REVIHAAP project. Technical report. World Health Organization 2013. <http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-air-pollution-and-review-of-eu-policies-the-revihaap-and-hrapie-projects> (accessed 12 April 2018).
4. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide 2013 Health risks of air pollution in Europe—HRAPIE project. *World Health Organization* p 72.
5. Aphekom – Improving Knowledge and Communication for Decision Making on Air Pollution and Health in Europe 2011 *Guidelines of methods for Integrating chronic effects of local-traffic pollution in the air pollution health impact methodology (WP4)* p 40.
6. Health risks of air pollution in Europe—HRAPIE project. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. World Health Organization. **2013**. <http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/health-aspects-of-air-pollution-and-review-of-eu-policies-the-revihaap-and-hrapie-projects> (accessed 12 April 2018)
7. Puett, R.C.; Hart, J.E.; Suh, H.; Mittleman, M.; Laden, F. et al. Particulate matter exposures, mortality, and cardiovascular disease in the health professionals follow-up study. *Environ. Health Perspect.* **2011**, *119(8)*, 1130–1135.
8. Guerreiro, C. B.; Foltescu, V.; Leeuw, F. 2014 Air quality status and trends in Europe. *Atmos. Environ.* **2014**, *98*, 376–384.
9. Beelen, R et al. 2008 Long-term effects of traffic-related air pollution on mortality in a Dutch cohort (NLCS-AIR study). *Environ Health Perspect.* **2008**, *116*, 196-202.
10. Stepanova, N. V.; Valeeva, E. R.; Fomina, S. F. Assessment of the total exposure to heavy metals of the child population city of Kazan. *Gig Sanit.* **2015**, *5*, 56-61.
11. Rakhmanin, J. A. et al. Guidelines for health risk assessment for the population on exposure to chemical substances polluting the environment (Moscow: Federal Center of the State Committee for Sanitary and Epidemiological Control), **2004** pp. 143
12. Avaliani, S.L.; Novikov, S.M.; Shashina, T.A.; Kislitsin, V.A.; Skvortsova, N.S: Experience of use of methodology of an assessment of risk to population health for ensuring sanitary and epidemiologic wellbeing: In: *Works of the All-Russian scientific and practical conference with the international participation* (Angarsk: RIO ATA). **2012**, 12-16.
13. Beelen, R.; Hoek, G.; van den Brandt, P. A.; Goldbohm, R. A.; Fischer, P.; Schouten, L. J., ... Brunekreef, B. (2008). Long-Term Effects of Traffic-Related Air Pollution on Mortality in a Dutch Cohort (NLCS-AIR Study). *Environ Health Perspect.* **2008**, *116(2)*, 196–202.
14. Fischer, P. H. et al. Air Pollution and Mortality in Seven Million Adults: The Dutch Environmental Longitudinal Study (DUELS). *Environ Health Perspect.* **2015**, *123 (7)*, 697–704.
15. Zhang P et al. Long-Term Exposure to Ambient Air Pollution and Mortality Due to Cardiovascular Disease and Cerebrovascular Disease in Shenyang (China). *PLoS ONE*. **2011**, *6*, 20827.
16. Stepanova N V, Valeeva E R, Main trends in children’s population health in the republic of tatarstan; *Gig Sanit*, **2015**, *1*, 92-97.
17. Fu, J.; Jiang, D.; Lin G.; et al. An ecological analysis of PM2.5 concentrations and lung cancer mortality rates in China. *BMJ Open*. **2015**, *5*: e009452.

18. Boldo E et al 2014 *Environ Res* **128** 15–26.
19. Burnett, R.T.; Pope, C.A. III; Ezzati, M. et al. An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. *Environ Health Perspect.* **2014**, *122*, 397–403.
20. Hoek, G.; Krishnan, R.M.; Beelen, R., et al. Long-term air pollution exposure and cardio-respiratory mortality: a review. *Environ Health.* **2013**, *12*, 43.
21. Cárđaba, Arranz M.; Muñoz, Moreno M.F.; Armentia, Medina A. et al. Health impact assessment of air pollution in Valladolid Spain. *BMJ Open.* **2014**, *4*: e005999.
21. Crouse, D.L.; Philip, S.; van Donkelaar, A. et al. A new method to jointly estimate the mortality risk of long-term exposure to fine particulate matter and its components. *Sci Rep.* **2016**, *6*, 18916.
22. Jerrett. M. et al. Spatial analysis of air pollution and mortality in California. *Am. J. Respir. Crit. Care Med.* **2013**, *188*, 593–599.
23. Kelly, F.J.; Fussell, J.C. Air pollution and public health: emerging hazards and improved understanding of risk. *Environ Geochem Health.* **2015**, *37*(4), 631-649.



© 2018 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).