The Risk of the Development of Non-Carcinogenic Effects from Exposure to Chemicals that Pollute the Atmospheric Air for the Health of Adolescents in an Urbanized Areas (Using the Example of Kazan)

E R Valeeva¹, C A Ismagilova¹, A I Ziyatdinova¹, D A Semanov¹

¹Institute of Fundamental Medicine and Biology, Kazan Federal University, Karla Markska str.74, Kazan, 420012, Russian Federation

E-mail: val_med@mail.ru

Abstract. Assessment of risk for adolescents due to atmospheric air pollution showed that the highest contribution to the total value of HI on inhalation route of entry was made by the suspended particulate matters PM₂.₅ and the spread of values in the districts was from 15.03 % to 18.68 %. 12.02% - 20.95%; carbon (soot) – (11.54% - 18.68%) and formaldehyde (4.88% - 9.47%) ranked second. An alarming level of risk for adolescents was identified in 1 (HI = 3.04) and 2 (HI = 3.23) zones of the city. The risk of diseases of the blood ranked second in general toxic action of chemicals. The total risk of developing non-carcinogenic effects in adolescents on entry of chemicals with atmospheric air corresponded to average level. The substances contributing the main percentage share to the risk of developing non-carcinogenic effects are carbon (soot), suspended particulate matters (PM₁₀ and PM₂.₅), nitrogen dioxide, carbon oxide, and formaldehyde

1. Introduction

At present, according to the data published by the WHO, the air pollution is the highest ecological risk in the world for the human health. The total contribution of the atmospheric air pollution is assessed by the WHO experts as equal to 3.2% of the global disease burden. Particular complexity lies in analysis of the long-term observations and contribution of certain compounds in case of multi-environment impact of a wide range of chemicals. The chemical factor of the environmental pollution ranks fourth in terms of the relative risk of the children morbidity giving place to hereditary and biological factors. According to data of the State Ecological Monitoring, more than 50% of the urban population is exposed to atmospheric air pollution, more than 35% of the surface sources of the drinking water supply and more than 15% of the underground sources fail to meet hygienic requirements [1]. About 150 000 of chemicals are registered in the field of use, and only 15% of them are studied in terms of toxicology, moreover, the chemicals market grows annually by 3% [2]. According to data of the WHO the approaches based on the health risk assessment have the form of a sequential systematic study of all aspects of the analyzed factor’s impact on human health including argumentation of the allowable exposure levels [3]. Children’s and adolescents’ exposure to environmental pollutants differs considerably from the adults’ exposure due to different causes associated with activity and behavioral risks, nutrition, and physiological metabolic peculiarities [4].
Determination of significance of chemical factor due to the impact of chemicals coming from the environment on the health of the children, the adolescents and the adult populations and justification of actions on control improvement, decrease and minimization of the risk levels for the health of major population groups with the account of regional peculiarities are important today. The impact of the environmental pollution and the atmospheric air in particular on the health of all population groups refers to strategic risks of Russia, the decrease of which requires the state approach and close interdepartmental interaction [5-10]. Urbanized territories occupy a special place when assessing the environmental quality and its basic factors having effect on human health. Review of publications on risk assessment in Russia showed that the main part of methodological questions was connected with uncertainties in exposure evaluation, the absence of regional, national and age differences in exposure factors and sensitivity to carcinogens.

In new economic conditions of market economy, the shift in the industrial priorities took place. Economic problems affected all spheres of public life, measures to support sanitary and epidemiological welfare and social protection of the population – unemployment, fall of living standards, growth of natural population decline, increase in crime rates, deterioration of food quality, and others [11-17]. The pattern of polluting the atmospheric air, the water sources and the urban soil cover with xenobiotics is caused by the specificity of industrial enterprises located in geographic and climatic, and economic zones, and that fact dictates the necessity of regional approach when studying the severity of exposure to technogenic pollutants and is a reason to analyze the impact of a variety of socio-economic factors on the health status of the oncoming generation.

Considering the urgency of the problem associated with chemical factor, the risk of developing non-carcinogenic effects was calculated to determine the impact of the atmospheric air pollutants on the health of adolescents and adult populations. Non-carcinogenic risk was characterized by the values of hazard quotients (HQ) and hazard indices (HI).

2. Methods
The risk of developing non-carcinogenic effects was assessed according to Guidelines П 2.1.10.1920-04 on hazard quotients. The calculation of daily doses on inhalation exposure to chemical substances was performed according to monitoring data of “The Center of Hygiene and Epidemiology in the RT (Tatarstan)” for the period from 2007 to 2017. For the period under study, 574 samples were taken according to form No.18. The assessment of exposure to chemicals via the ingestion, inhalation and dermal routes was carried out with application of the assessment of chronic daily intake (ADDch) with application of standard formulas [18]. The non-carcinogenic risk was assessed based on hazard quotients (HQ) for each substance with application of standard and regional exposure factors at the median level (Ме) - usual exposure range, and the 95-th Percentile (Р95) level - maximum reasonable exposure (formula 1).

\[ \Sigma HQ = \frac{ADD}{RfD} \]  
\[ THI = \Sigma HQ \]  

A characteristic of the total toxic effects was made based on hazard quotients (HQ) of certain substances and total hazard indices (HI) for substances with unidirectional mechanism of action [18]. The values of HI from 1.1 to 3.0 were taken for the allowable level of non-carcinogenic effects, the range of HI values from 3 to 6 was regarded as an alarming risk level, and HI higher than 6 – as high one. Probabilistic approaches on the basis of the health risk assessment as the result of chemicals’ effects based on average annual concentrations and their upper 95%-th confidence limits determined by average daily concentrations in environmental compartments are considered to be a modern and more accurate approach to assessing the formation of pathological changes in the human body [19].
3. Results
We analyzed 4 districts of the city of Kazan: the 1-st zone - Kirovsky, the 2-nd zone - Privolzhsky, the 3-rd zone – Sovietsky, and the 4-th one – Vakhitovsky. Two age groups: the adolescents (15-17 years old) and the adult population were taken into consideration. The non-carcinogenic risk was characterized by the values of hazard quotients (HQ) and hazard indices (HI). To calculate the exposure, the median and the 95-th % Perc of the chemicals’ content in the atmospheric air were used. Statistical analysis of the obtained data was implemented in operating system Windows 2010 with the use of standard application program packages Excel 2010. Calculation of daily doses on inhalation exposure to chemical substances was performed according to monitoring data of “The Center of Hygiene and Epidemiology in the RT (Tatarstan)” for the period from 2007 to 2017.

Current trends of Russian economy identified 20 largest industrial regions of Russia, which account for 2/3 of national industrial output (67% in 2016). The output of extractive industries accounts for 70.4%, that of manufacturing sector - 66.9%, and that of the sector “Production and distribution of electrical energy, gas and water” - 60.9%. Today Tatarstan ranks fifth on the list of the most developed industrial regions of Russia, whereas it was included into the group with diversified economy (Tatarstan and the Sverdlovsk Region/Oblast).

Industrial Production Index in Kazan made 104.8% at year-end 2018. Tatarstan ranked fourth in the rating of Russian regions in quality of life. The researchers noted that 10 regions-leaders, among which was also Tatarstan, gave half of the internal regional product, 40% of the trade turnover and 40% of investments to the country. Kazan is a city with a million-plus population, and it occupies the 7-th place in terms of the population size in the RF (1.133 million people). About 360 types of chemical pollutants with total weight of about 104-107 thousand tons, where the proportion of industrial emission in overall pollution makes 29.4–32 thousand tons, are annually emitted into the atmospheric air of the city [20].

Toxic substances of the first and second hazard categories (chromium. benzol. phenol. acrolein. formaldehyde) and substances with low irritation threshold (hydrogen sulphide. ammonia. sodium hydroxide. and etc.) are among impurities deteriorating the air quality in the city. More than 67.5 % of all emissions from stationary sources are formed by “Kazanorgsintez”. about 10 % – by HPS-1 (Heat and Power Station) / TETs – 1. Significant pollution is produced by HPS-2 / TETs – 2, MUE PA (Municipal Unitary Enterprise Production Association) “Kazenergo”, LLC (Limited Liability Company) /OOO “Kazan Plant of Silicate Wall Materials”.

When comparing total risks of non-carcinogenic effects of the chemicals polluting the atmospheric air, difference between the values of the hazard quotient for adolescents and adults was revealed: this index was higher in adolescents. than in adults with maximum gap in the 4-th zone (Fig.1).
According to the analysis results it was determined that the 1-st zone was the zone with maximum exposure to chemicals, because the total hazard index made HI=7.98 (95% Perc). A number of substances exerting the highest impact were revealed. They included carbon (soot), suspended particulate matters PM \(_{2.5}\), nitrogen dioxide, suspended solids [5].

In the rest zones under study in the city of Kazan the total hazard index had the following values (in descending order): the 4-th zone (HI=6.66), the 1-st zone (HI=5.59), the 3-rd zone (HI=4.52), where the major pollutants were: nitrogen dioxide, carbon (soot), suspended solids (Table 1).

**Table 1.** The results of the assessment of the total risk of non-carcinogenic effects from chemicals that pollute the air for teens in Kazan (by districts).

| Chemical substance                  | 1 zone | 2 zone | 3 zone | 4 zone |
|------------------------------------|--------|--------|--------|--------|
| Nitrogen dioxide                   | 1.43   | 0.67   | 0.85   | 1.40   |
| Sulfur dioxide                     | 0      | 0      | 0      | 0      |
| Carbon oxide                       | 0.44   | 0.16   | 0.28   | 0.42   |
| Carbon (soot)                      | 1.49   | 0.64   | 0.69   | 1.11   |
| Suspended substances               | 1.26   | 1.03   | 0.82   | 0.96   |
| Suspended substances PM10          | 0.94   | 0.95   | 0.61   | 0.75   |
| Suspended substances PM2.5         | 1.61   | 1.61   | 1.02   | 1.29   |
| Petrol                             | 0.17   | 0      | 0.03   | 0.10   |
| Formaldehyde                       | 0.64   | 0.51   | 0.22   | 0.63   |
| Benz (a) pyrene                    | 0      | 0      | 0      | 0      |
| Benzene                            | 0.003  | 0      | 0      | 0.002  |
| HI                                 | 7.98   | 5.59   | 4.52   | 6.66   |

In conditions of combined exposure, the highest toxicological burden falls on the main critical target-organs: the respiratory system (HI = 3.04 – 2.36), the blood (HI = 0.84 – 0.53), the disorders having impact on general development of the human body and diseases, the CVD (HI = 0.63 – 0.55), the CNS (HI = 0.29 – 0.21). Distribution of the hazard quotient values for the respiratory system in the city districts showed: HI = 2.37 (the 4-th zone), HI = 2.38 (the 3-rd zone), which corresponded to low risk level. The values of the total hazard quotient in the 1-st zone (HI = 3.04) and the 2-nd zone (HI =
3.23) indicated the alarming health risk level. General toxical action of chemicals on diseases of the blood was distributed in the following way: the 1-st and the 4-th zones were the leaders, where the values were HI = 0.84 and HI = 0.81 correspondingly, next the 2-nd zone (HI=0.66) and the 3-rd zone (HI=0.53).

4. Discussion
The highest risk values of non-carcinogenic effects of the disorders having impact on general development of the human body and cardiovascular diseases were practically the same and were observed in the 1-st zone (HI = 0.63) and in the 2-nd zone (HI = 0.62). In the rest districts the risk was equal to 0.56 – 0.55. As far as the impact of chemicals on the CNS, the values were the same in the 1-st and the 3-rd zones and made HI = 0.28. In the 2-nd and the 3-rd zones the values were close HI = 0.26 – 0.21. Difference in disorders having impact on general development of the human body was observed in the Privozhsky district (HI = 0.87), being the highest value among the analyzed districts. The lowest levels of the risk of developing non-carcinogenic effects on chronic inhalation of chemicals were manifested by the impact on the eyes, the liver, the kidneys, the red marrow, the reproductive and hormone systems [21-27].

The analysis of data in the Privozhsky district revealed that ranking of the major chemicals in respect of contribution to the total hazard quotient had its own peculiarities. Suspended particulate matters PM 2.5 (17.95%) were the substances making the basic percentage of the risk of developing non-carcinogenic effects, benz[a]pyrene (16.09%) ranked second, and nitrogen dioxide (13.93%) ranked third. The proportion of the rest substances was small. Their values being 6.0%, 5.29% and 5.39% in the 2-nd, the 3-rd and the 4-th zones correspondingly.

| Substance          | 1 zone | 2 zone | 3 zone | 4 zone |
|--------------------|--------|--------|--------|--------|
| Nitrogen dioxide   | 17.93  | 12.02  | 18.73  | 20.95  |
| Sulfur dioxide     | 0      | 0      | 0      | 0      |
| Carbon oxide       | 5.53   | 2.89   | 6.25   | 6.25   |
| Carbon (soot)      | 18.68  | 11.54  | 15.17  | 16.65  |
| Suspended substances| 15.75  | 18.40  | 18.15  | 14.47  |
| Suspended substances PM10 | 11.83  | 17.07  | 13.61  | 11.30  |
| Suspended substances PM2.5 | 20.14  | 28.87  | 22.58  | 19.36  |
| Petrol             | 2.10   | 0      | 0.62   | 1.51   |
| Formaldehyde       | 7.99   | 9.19   | 4.88   | 9.47   |
| Benz (a) pyrene    | 0      | 0      | 0      | 0      |
| Benzene            | 0.04   | 0      | 0      | 0.02   |

Table 2. Share of influence of chemicals affecting the health of adolescents in Kazan.

Priority atmospheric air pollutants such as suspended particulate matters PM 2.5, nitrogen dioxide, carbon (soot) were identified on ranking of chemicals in terms of the value of hazard quotient. The calculation of the hazard quotient as far as certain pollutants allowed determining the contribution to the total value of the hazard index: suspended particulate matters PM2.5: 19.36% - 28.87%. nitrogen dioxide: 12.02% - 20.95%, carbon (soot): 11.54% - 18.68%. and formaldehyde: 4.88% - 9.47%. The following distribution proved to be interesting: the highest index in suspended particulate matters PM2.5 (28.87%) was in the 2-nd zone, whereas in the 4-th zone, it was the lowest (19.36%). The highest impact ratio of nitrogen dioxide (20.95%) also fell on the 4-th zone (Table 2).

Contribution of chemicals showed that nitrogen dioxide, which amounted to 20.95%, ranked first in the impact of negative factors on the adolescents’ health in the 4-th zone, whereas in the 1-st and the 3-rd zones, there was the highest index of carbon (soot) - 17.93% and 18.73% correspondingly. Suspended particulate matters PM 2.5 ranked third and the spread of values in the districts made from
14.47% to 18.40%. The given conclusions about the medical aspects of air pollution in accordance with the REVIHAAP and HRAPIE WHO/EC projects confirm that external air pollution is an important health risk factor and a key factor of diseases and mortality all over the world [28-29]. Pollution with PM contributes significantly to formation of the burden of diseases reducing average life expectancy almost by 9 months in Europe. In some most polluted cities of Europe the life expectancy can be increased approximately by 20 months. if the presence of PM$_{2.5}$ in the air is reduced to the levels recommended by the WHO [30]. In recently published research dealing with the global burden of diseases, pollution of atmospheric air with fine PM ranked eighth in the structure of the leading risk factors: up to 3.2 mln premature deaths in the world annually [31].

5. Conclusion
Assessment of risk for adolescents due to atmospheric air pollution showed that the highest contribution to the total value of HI on inhalation route of entry was made by the suspended particulate matters PM$_{2.5}$ and the spread of values in the districts was from 15.03 % to 18.68 %. 12.02% - 20.95%; carbon (soot) – (11.54% - 18.68%) and formaldehyde (4.88% - 9.47%) ranked second. An alarming level of risk for adolescents was identified in 1 (HI = 3.04) and 2 (HI = 3.23) zones of the city. The risk of diseases of the blood ranked second in general toxic action of chemicals. The total risk of developing non-carcinogenic effects in adolescents on entry of chemicals with atmospheric air corresponded to average level. The substances contributing the main percentage share to the risk of developing non-carcinogenic effects are carbon (soot), suspended particulate matters (PM$_{10}$ and PM$_{2.5}$), nitrogen dioxide, carbon oxide, and formaldehyde.

6. References
[1] Kombarova M Yu 2018 Chemical safety of the Russian Federation. Problems and solutions Medicine of extreme situations 3 383-397
[2] Global Chemicals Outlook: Towards sound Management of Chemicals Synthesis Report for Decision-Makers United Nations Environment Programme 2012 http://www.saicm.org/index.php?option=com_ content&view=article&id=89:iccm-3-meeting-documents&catid=90:iccm-3&Itemid=600
[3] 2010 Action is needed on chemicals of major public health concern WHO http://www.who.int/ipcs/features/10chemicals_en.pdf
[4] Alves S 2012 US EPA Authority to Use Cumulative Risk Assessments in Environmental Decision-Making DC Payne-Sturges. Int. J. Environ. Res. Public Health 9 1997-2019
[5] Child-specific exposure factors handbook: EPA/600/R-06/096F September 2008
[6] Rakhmanin Yu A 2012 Actualization of the problems of human ecology and environmental hygiene and ways to solve them Hygiene and Sanitation №5 4-8
[7] Rakhmanin Yu A, Sinitsyna O O 2013 The state and the actualization of tasks to improve the scientific. methodological and regulatory framework in the field of human ecology and environmental hygiene Hygiene and Sanitation 5 4-10
[8] Rakhmanin Yu A 2016 Hygienic assessment of atmospheric air in areas with varying degrees of development of the road-automobile complex Hygiene and sanitation 95(12) 1117-1121
[9] Valeeva E R, Ismagilova G A, Ziyatdinova A 2018 Assessment of Non-Carcinogenic Adolescent Health Risk from Drinking Water Research journal of pharmaceutical biological and chemical sciences vol 9 2 15-19
[10] May I V 2013 Establishment and proof of harm to the health of a citizen caused by the negative impact of environmental factors Public health and the environment 11(248) 4-6
[11] Prusakov V M 2013 The dynamics of the risk of morbidity in the industrial cities of the Irkutsk region Hygiene and Sanitation 5 63–69
[12] Rusakov N V 2016 Methodological problems of non-infectious epidemiology and hygiene during chemical pollution of the environment Hygiene and Sanitation 9 797-800
[13] Zhurkov V S 2013 Harmonization with international approaches of methodological documents on methods for evaluating mutagenic properties of chemical environmental factors Hygiene and Sanitation 6 49-52
[14] Zaitseva N V 2013 Study of the health of the population living in the zone of influence of a large industrial enterprise using risk assessment and epidemiological research methods Human Ecology 12 33-38
[15] Ivanov V P, Vasilyeva O V, Polonikov A V 2012 Scientific and methodological foundations for assessing the risk to public health in a complex environmental-hygienic study of territories Human Ecology 11 11-16
[16] Kashapov M G 2008 Hygienic assessment of the influence of environmental factors on the health of adolescents in the oil and gas producing region Hygiene and Sanitation 4 15–18
[17] Onishchenko G G 2014 Health risk analysis in the tasks of improving sanitary and epidemiological surveillance in the Russian Federation Health risk analysis 2 4-13
[18] Kulesh D V, Kolesnikov S I, Dolgikh V V, Shoyko S V, Abashin N N, Cherkashin A G, Lebedeva L N 2013 Regional environmental and socio-economic aspects of the incidence of adolescent population in conditions of residence in industrial centers Bulletin of the Russian Academy of Medical Sciences 3 62-87
[19] R 2.1.10.1920-04 2004 A guide to assessing the risk to public health when exposed to chemicals that pollute the environment M: Federal center of state sanitary and epidemiological supervision of the Ministry of Health of Russia 143
[20] Fletcher R 1998 Clinical epidemiology Basics of evidence-based epidemiology M.: Media Sphere 352
[21] State report "On the state of natural resources and environmental protection of the Republic of Tatarstan in 2016" (Kazan) 508
[22] Gasilin V V 2013 Evaluation of the risk to the health of the population of the city of Kazan from exposure to chemicals that pollute the air (according to laboratory studies of various departments) Health Risk Analysis 3 41-45
[23] Zhurkov V S 2013 Harmonization with international approaches of methodological documents on methods for assessing the mutagenic properties of chemical environmental factors Hygiene and Sanitation 6 49-52
[24] Novikov S M, Unguryanu T N 2014 Evaluation of chemical effects on the working population in single-industry towns Hygiene and sanitation 5 74-78
[25] Novikov S M 2013 Actual problems in the system of state regulation of chemical safety Hygiene and Sanitation 4 74-78
[26] Prosiviryakova I A, Shevchuk L M 2018 Hygienic assessment of the content of particulate matter and PM10 and PM2.5 in atmospheric air and the risk to the health of residents in the zone of influence of emissions from stationary sources of industrial enterprises Analysis of Health Risk 2 14-22
[27] Horpyakova T V, Pasichna O M 2013 Assessment of the level of air pollution and aerotechnogenic risk to public health Bulletin of the Tambov University. Series: Natural and Technical Sciences 3 914-918
[28] Sahu S K, Zhang H, Guo H et al 2019 Air Quali Atmoshere Health 2.5 in Indian cities 12 327
[29] Héroux M E 2013 Key findings on the medical aspects of air pollution: REVIHAAP and hrapie projects WHO/EC Hygiene and Sanitation 6 9-14
[30] Zastenskaya I 2013 The potential of the Member States of the WHO European Region in the field of prevention of negative effects of chemicals on public health and measures to strengthen it Hygiene and Sanitation 5 11-15 (for soil and for air)
[31] Medina S 2012 Summary report of the Aphekom project 2008-2011 Aphekom http://www.endseurope.com/docs/110302b. pdf
[32] Lim S S, Vos T.Flaxman A D, Danaei G, Shibuya K, Adair Rohani H et al 2013 A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor
clusters in 21 regions 1990-2010: a systematic analysis for the Global Burden of Disease Study (Lancet) 380(9859): 2224–60. doi:10.1016/S0140-6736(12)61766-8

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.