The impact of traffic density on population health in the city of Kazan

El impacto de la densidad del tráfico en la salud de la población de la ciudad de Kazán

Natalya Vladimirovna Stepanova[1], Saifullin Rustem Rashitovich[2], Emiliya Ramzievna Valeeva[3], Ilyasova Alisa Raifovna[4], Suryana Faritovna Fomina[5], Salakhov Niyaz Vagizovich[6]

[1]Doctor of Medical Sciences, Professor, Department of Bioecology, Hygiene and Public Health, Institute of Fundamental Medicine and Biology, Kazan Federal University; e-mail: stepmed@mail.ru +79173999907. ID Scopus 56712449900

[2]Candidate of biological sciences, Associate Professor, Department of Bioecology, Hygiene and Public Health, Institute of Fundamental Medicine and Biology, Kazan Federal University; e-mail: Saifullin1955@ mail.ru. ID Scopus 57188566510

[3]Doctor of Medical Sciences, Professor, Department of Bioecology, Hygiene and Public Health, Institute of Fundamental Medicine and Biology, Kazan Federal University; e-mail: val_med@mail.ru. ID Scopus 6506857648

[4]Candidate of biological sciences, Associate Professor; Department of Bioecology, Hygiene and Public Health, Institute of Fundamental Medicine and Biology, Kazan Federal University; e-mail: lie4ka_101@mail.ru.

[5]Graduate student Department of Bioecology, Hygiene and Public Health, Institute of Fundamental Medicine and Biology; e-mail: isuryana@mail.ru. ID Scopus 57034032300

[6]Candidate of biological sciences, Associate Professor; Department of Bioecology, Hygiene and Public Health, Institute of Fundamental Medicine and Biology, Kazan Federal University; email: sresearch2484@yahoo.com. ID Scopus: 57200699686

Received/Recibido: 08/28/2020 Accepted/Aceptado: 09/15/2020 Published/Publicado: 11/09/2020 DOI: 10.5281/zenodo.4426194

Abstract

The growth of the vehicles' number in the cities, the proximity of automobile traffic to residential areas, poor road maintenance and emission toxicity exacerbate the problem of the atmospheric air quality in the cities. Assessment of exposure to solid particles, PM10 and PM2.5 in the four districts was carried out based on average annual concentrations performed by "FSBI (Federal State Budgetary Institution) "Hydrometeorology and Environmental Monitoring Administration of the Republic of Tatarstan" (HEMA RT) and the Municipal Institution "Automated traffic control system" (MUE ATCS) at the Air Pollution Observation Stations (APOS) between 2015 and 2018. The risk assessment of the development of non-carcinogenic effects from pollutants contained in the air was carried out according to the total hazard index. According to assessment results, the total exposure to particulate matters PM2.5, PM10 and total dust (TSP) made the major contribution to the total value of non-carcinogenic risk: 46.2% - 80.3%. Organs of the respiratory system (RHI =9.76; 5.7; 8.86 and 15.28) are highly vulnerable to the risk of developing general toxic effects on chronical exposure to chemicals coming from atmospheric air. The calculation of the traffic intensity was performed during air sampling at the APOS. The results of the analysis showed the necessity of shifting the time of the atmospheric air status control at the APOS by 1 hour, which can result in compliance with the sampling time to a peak of traffic flow. The most reliable analytical tool for determination of priorities on managerial decision making is methodology of health risk analysis.

Key words: Atmospheric Air, Public Health Risk Vehicles, Monitoring.

Resumen

El crecimiento del número de vehículos en las ciudades, la proximidad de fuentes móviles a las zonas residenciales, el mal mantenimiento de las carreteras y la toxicidad de las emisiones agravan el problema de la calidad del aire atmosférico en las ciudades. La evaluación de la exposición a partículas sólidas, PM10 y PM2.5 en los cuatro distritos se llevó a cabo sobre la base de las concentraciones anuales promedio realizadas por "FSBI (Institución Presupuestaria del Estado Federal)" Administración de Monitoreo de Hidrometeorología y Medio Ambiente de la República de Tatarstán "(HEMA RT) y la Institución Municipal "Sistema Automatizado de Control de Tráfico" (MUE ATCS) en las Estaciones de Observación de Contaminación Atmosférica (APOS) entre 2015 y 2018. La evaluación de riesgo de desarrollo de efectos no cancerígenos por contaminantes contenidos en el aire se realizó de acuerdo a el índice de riesgo total. Según los resultados de la evaluación, la exposición total a las partículas PM2.5, PM10 y el polvo total (TSP) hizo la mayor contribución al valor total del riesgo no cancerígeno: 46,2% - 80,3%. Los órganos del sistema respiratorio (RHI = 9,76; 5,7; 8,86 y 15,28) son altamente vulnerables al riesgo de desarrollar efectos tóxicos generales por exposición crónica a sustancias químicas provenientes del aire atmosférico. El cálculo de la intensidad del tráfico se realizó durante el muestreo de aire en el APOS. Los resultados del análisis mostraron la necesidad de cambiar el tiempo del control del estado del aire atmosférico en el APOS en 1 hora, lo que puede resultar en el cumplimiento del tiempo de muestreo a un pico de flujo de tráfico. La herramienta analítica más confiable para la determinación de prioridades en la toma de decisiones gerenciales es la metodología de análisis de riesgos para la salud.

Palabras clave: Aire atmosférico, Vehículos de riesgo para la salud pública, Monitoreo.

Introduction

Concentration monitoring and decrease of air pollution with in urbanized cities is a crucial task of social and hygienic monitoring and risk management for the population health. The most reliable analytical tool on managerial decision making, which is widely applied in the world, is methodology of health risk analysis allowing revealing the priority and the most cost-efficient measures for achieving optimal quality of the environment[1,2,3].

The architectural and planning peculiarities of large cities affect the processes of pollutants' dissipation; predetermine the growth of the vehicle engine idle time resulting from the motor vehicle standing at the street junctions, contributing to higher emission of hazardous substances into the atmospheric air. The growth of the vehicles' number in the cities, the proximity of automobile traffic to residential areas, poor road maintenance and emission toxicity exacerbate the problem of the atmospheric air quality, despite the decrease of industrial emissions[4,5,6]. Numerous epidemiological studies indicate adverse health effects from exposure to atmospheric air pollution[7,8]. Particulate matter (PM) air pollution is a persistent problem in the large populated area. Major sources of PM air pollution in urban areas include exhaust emissions, road dust resuspension (traffic related and pavement surface abrasions)[9]. Road transport emissions directly affect pedestrians in urban areas, while particulate matter concentrations are often alarming and go beyond the limit on protection of human health[10]. Different particle sizes, composition, or characteristics can be related to specific emission sources better than other air pollutants and may therefore be considered a (more) suitable indicator. Thus, PM10 may be an appropriate indicator when considering the impact of resuspension of road dust, while black carbon is a more sensitive indicator for exhaust emissions from road traffic[11]. It is therefore important in an AP-HRA to select the appropriate pollutants for the sources that are relevant to the exposure of the targeted population. PM2.5 has been investigated in many epidemiological studies, and has been shown to be a robust indicator of risk associated with exposure to PM from diverse sources and in different environments[12].

The issues of external quality control and regulation of the state of the atmospheric air are becoming relevant. This makes it imperative to pursue risk-reduction measures, and decision-support tools devised, based on analyses and risk assessments. Results of systemic instrumental measuring that is performed within state systems of ecological and social-hygienic monitoring are considered to be the most informative and reliable database to assess efficiency of air-protecting activities.

Methods

Assessment of exposure to the pollutants coming with vehicles' emissions in four districts of the city of Kazan was carried out based on the results of retrospective studies of average annual concentrations at the Air Pollution Observation Stations (APOS) between 2015 and 2018. Monitoring of atmospheric air pollution in the city of Kazan is carried out by FSBI (Federal State Budgetary Institution) "Hydrometeorology and Environmental Monitoring Administration of the Republic of Tatarstan" (HEMA RT) to a high standard at the air pollution observation stations (APOS). Sampling is carried out during 20 minutes 4 times a day at intervals of 6 hours: 1.00 a.m., 7.00 a.m., 1.00 p.m., and 7.00 p.m. with subsequent analysis. The obtained information contains data on maximum single and average daily concentrations of pollutants. The assessment of epidemiological risk for the population health in the city's microdistricts was carried out for the first time. The assigned areas corresponded geographically to the location of APOS: APOS-3 in the Vakhitovsky district; APOS-8 in the Sovetsky district; APOS-11 in the Novo-Savinovsky district and APOS-15 in the Gorki (Table1).

Table 1. Location of APOS

APOS	Location	City districts
APOS -3	Pravobulachnaya str.	Vakhitovsky
APOS -8	Kazansky sanatorium	Sovetsky
APOS -11	Lavrentiev str.	Novo-Savinovsky
APOS -15	Intersection of Fuchik and Zorge streets	Gorki

Information on the traffic intensity in the city of Kazan was additionally completed with the data from the MUE ATCS, the principal activity of which is the road-traffic safety with computer use. Implementation of adaptive traffic control system was approved by the Government of the Republic in the year of 2010. The OMNIA system of the SWRCO group of companies with functional application on concession of priority to public transport traffic was taken as a basis. So far, a soft and hardware complex for traffic optimization is implemented at 128 traffic-light crossroads, primarily in the center of the city. All information obtained from the equipment is transmitted to the control center ATCS. Video detectors mounted at the approaches to traffic lights keep a record of the vehicle number, data on traffic flows and traffic load. Based on the obtained information the system elaborates the strategy of controlling a group of traffic lights, optimizing the traffic on a 24-hour basis. Assessment of traffic intensity is carried out by averaging the number of vehicles passing over the crossing near the APOS within 30 minutes during air sampling: 1.00 a.m., 7.00 a.m., 1.00 p.m., and 7.00 p.m. The risk assessment of the development of non-carcinogenic effects from pollutants contained in the air was carried out according to the total hazard index (HI) in line with Guidelines in the "Guide to Public Health Assessment of Environmental Pollution" R 2.1.10.1920-04[13]. The level of non-cancer risk was determined by way of comparing the factual levels of chemical exposure with the safe exposure levels. The hazard quotients (HI) were calculated for chronic exposure. The health risk assessment in Kazan was performed with the use of the data about the average annual concentrations of substances in the atmospheric air in 2015-2018.

Results and Discussion

The analysis of laboratory studies of the atmospheric air in the city of Kazan showed that 7–12 pollutants were controlled at the APOS. 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 of the Russian Federation and the inventory list of toxic substances' emission of the U.S. EPA. For the period under study, the contribution of the automobile transport to atmospheric pollution in Kazan remained high and contributed 69.4%–73.8% of the total gross emissions. Average annual concentrations of suspended particulate matters PM10 exceeded the MAC at the APOS -3, APOS-11 and APOS-15 by a factor of 1.2. – 7.1, and in PM2.5 – by a factor of 2.1 and 3.8, correspondingly. APOS-8 was identified as a control one in the content of PM10 and PM2.5 fractions, the level of which was within the limits of regulations (Table 2).

Table 2. Average annual concentrations of pollutants in the atmospheric air at APOS of the city

	[a]MAC a.d. mg/m^3 [b]C mg/m^3	APOS -3	APOS -8	APOS -11	APOS -15
Suspended particulate matters	0.15	0,018	0,0392	0	0,0138
Carbon oxide	3.0	0.765	0.405	0	0.315
Nitrogen dioxide	0,04	0.0556	0.0268	0	0.0232
Hydrogen sulphide	0.02	0.0038	0.0044	0.0036	0.0037
Phenol	0.006	0.00063	0.0003	0.00039	0.0003
Ammonia	0.1	0.044	0.0265	0.0255	0.028
Formaldehyde	0.003	0.00585	0.003825	0.006705	0.005595
Sulphur dioxide	0.02	0	0	0	0.0001
PM_{10}	0.04	0.098	0.041	0.0475	0.2875
$PM_{2.5}$	0.025	0.052	0.025	0.02063	0.0961

[a] MAC a.d., –allowable average daily concentration; [b]C – substance concentration (mg/m^3);

Analysis of data on atmospheric air monitoring for the years of 2016-2019 was characterized by general tendency: decrease of cases exceeding maximum allowable single concentration (MAC m.s.). Maintenance of high (higher than MAC a.d.) levels of nitrogen dioxide content was observed at APOS-3 during the whole period of observation. We assessed the health risk for the population of the city of Kazan in the specified districts due to the atmospheric air pollution (Table 3).

Table 3. Results of assessing non-carcinogenic risk from chemicals polluting atmospheric air for the population health in APOS of the city of Kazan

Points	RfC mg/m^3	APOS 3		APOS 8		APOS -11		APOS -15	
Substances		HQ	%	HQ	%	HQ	%	HQ	%
TSP	0.04	0.45	4.41	0.98	16.11	2.23	22.60	0.345	2.22
Carbon Oxide	3.0	0.255	2.50	0.135	2.22	0.81	8.23	0.105	0.67
Nitrogen Dioxide	0.04	1.39	13.62	0.67	11.02	1.75	17.78	0.58	3.72
Hydrogen Sulphide	0.02	0.19	1.86	0.22	3.62	0.18	1.83	0.185	1.19
Phenol	0.006	0.105	1.03	0.05	0.82	0.065	0.66	0.05	0.32
Ammonia	0.1	0.44	4.31	0.265	4.36	0.255	2.59	0.28	1.80
Formaldehyde	0.003	1.95	19.11	1.275	20.96	2.235	22.70	1.865	11.98
Sulphur Dioxide	0.02	0	0.00	0	0.00	0	0	0.005	0.03
PM_{10}	0.05	1.96	19.20	0.82	13.48	0.95	9.65	5.75	36.93
$PM_{2,5}$	0.015	347	33.96	1.67	27.40	1.38	13.97	6.41	41.14
HI		10.21	100.0	6.08	100.0	9.84	100.0	15.57	100.0
RHI		9,76	100	5,73		8,86		15,28	

[a]RfC - reference concentration; [b]HQ - hazard quotient; [c]HI—the total hazard index with account of total dust (TSP), particulate matter $(PM)_{10}$, and $PM_{2.5}$ fractions. [d]RHI —–the total respiratory hazard index (with account of respiratory diseases)

There are no industrial enterprises in locations of APOS selected for the study (Table 1). The pollution level at the stations (apart from APOS – 8) is determined mainly by vehicle emissions. The calculation of the traffic intensity was performed during air sampling at the APOS. At APOS-3, the periods with maximum traffic were registered in the morning from 8.20 a.m. - 8.40 a.m. (8% of all maximums within a year), and in the evening between 6.00-6.20 p.m. (10 %) and between 5.00 p.m. – 5.20 p.m. (14%). The air sampling time agrees with neither maximum of the traffic flow, and this fact results in a discrepancy in the morning – 52% of the total maximum traffic, and in the evening – 24%. At APOS- 8, the traffic intensity increases after 7.00 a.m., and the difference between 7.00 a.m. -7.20 a.m. and 7.20 a.m. – 7.40 a.m. makes 23%, and between the last one and 8.40 a.m. - 9.00 a.m. – 37%. At APOS-11 and APOS-15 the periods with maximum traffic were registered in the morning from 7.00 a.m. - 9.00 a.m., and in the evening from 4.40-6.00 p.m. (Table 4).

Table 4. Maximums of vehicle passage at time of day intervals (the number of vehicles)

Time interval	APOS -3	APOS -8	APOS -11	APOS -15
1.00-1.20	577	1094	1132	1134
2.00-2.20 7.00-7.20 7.40-8.00	409 2414 2577	739 6839 7055	747 10275 12204	850 10671 11378
8.00-9.00	2259-2948	7089 - 7616	10260-11966	10298-11966
13.00-13.20	2838	7729	8859	8293
14.00-14.20	2867	7760	8979	8107
16.40-17.00 17.20-17.40 17.40-18.00	2550 2601 2544	7800 8426 8389	9243 12321 12154	9062 10006 9801
18.00-18.20 18.20-18.40	2931 2474	9024 8101	12101 11736	9873 9615
18.40-19.00 19.00-19.20	2280 2362	7245 6812	11277 10708	8956 8542

As for stations APOS-11 and APOS -15, periods with maximum traffic fall on 7.20-7.40 a.m. and 5.20-5.40 p.m. For APOS-11, mismatch of atmospheric air sampling time with time of maximum traffic flow makes 20% from 7.00-7.20 a.m., and 15% from 7.00-7.20 p.m. As far as APOS -15, this indicator made 12% from 7.00-7.20 a.m. and 12% and 17% in the evening. The results showed that the air sampling time from 7.00-7.20 a.m. and from 7.00-7.20 p.m. agreed with none of traffic flow maxima, and this fact resulted in general discrepancy of 52% in the morning, and 24% in the evening. According to the level of the traffic mitigation, the districts under study are arranged as follows; the crossroads at the APOS -11, APOS -15, APOS - 8 and APOS - 3.

Summary

Analysis of the total hazard index (HI) in the districts under study showed that non-carcinogenic risk at all APOS -3; 11; 15 corresponded to high risk level (HI was greater than 6.0)[13]. According to assessment results, the total exposure to particulate matters PM2.5, PM10 and total dust (TSP) made the major contribution to the total value of non-carcinogenic risk: in the area of APOS -3 and APOS – 8 (57.0 – 57.6%), APOS – 11 – 46.2%; and the greatest contribution of 80.3% was registered in the area of APOS - 15. Second in importance at all APOS was formaldehyde, its proportion of contribution varying from 11.98% at APOS-15 to 19.11% - 22.70% at the rest of sampling points. The main source of formaldehyde in the city is vehicles. According to research data, the level of pollution with formaldehyde in the areas adjacent to the highways was 1.6 times higher than in the residential area. The width of zones polluted with formaldehyde makes from 50 to 140 meters from the highway center lines[14]. In the assessment of the combined health effects associated with the chemical contaminants in the outdoor air the hazard indices (HI) were calculated accounting for the critical organs (systems) affected by the analyzed substances. The chronic non-cancer risk affecting the respiratory organs in the APOS-15 is caused by the combined exposure to PM10 (37.6%), PM2.5 (41.9%), formaldehyde (12.2%), nitrogen dioxide (3.8%), suspended solids (2.3%), as well as ammonia (1.8%), phenol (0.33%) and sulfur dioxide (Table 3). And only on the territory of the APOS -5 location, the level of non-carcinogenic risk for respiratory system was alert, suggesting carrying out of health-improving measures for the population living on these territories. According to assessment results, the total exposure to particulate matters PM2.5, PM10 and total dust (TSP) made the major contribution to the total value of non-carcinogenic risk: 46.2% - 80.3%. Organs of the respiratory system (RHI = 9.76; 5.7; 8.86 and 15.28) are highly vulnerable to the risk of developing general toxic effects on chronical exposure to chemicals coming from atmospheric air. The results of the analysis showed the necessity of shifting the time of the atmospheric air status control at the APOS by 1 hour, which can result in compliance with the sampling time to a peak of traffic flow.

Conclusions

Epidemiological and toxicological data show that a mass of PM (PM2.5, PM10) contains fractions of varying types and degrees of the health impact. Our results corroborate the existing evidence of the fact that atmospheric air pollution is a significant environmental risk factor for the population health[3,11]. High risks of developing non-carcinogenic effects for the population of the city of Kazan and the districts under study were associated with total exposure to suspended particulate matters. Meanwhile, in scientific literature, clear emphasis is placed on the opinion that quantitative methods of analysis and risk assessment form the basis of safety management, as part of critical infrastructure[15]. This is especially of concern in urban areas, where large numbers of people live near substantial road traffic emissions. The biggest air pollutants are motor vehicle. Because of that, the hygienic standards are always exceeded in the close proximity to major highways both in Kazan and in the country in general[16]. For example, in 2015, the fraction of nonstandard air samples collected at the Russian Federation highways near the residential areas totaled 2.5%, and near the industrial plant areas – 0.98%[17]. There was established the dependence of the level of air pollution on traffic flows in locations of the city of Saint Petersburg. Pollutants were shown to enter the air environment mainly in the form of fine dust particles. Rakhmanin and Levanchuk[6], there was justified the need for the control of products of wear the road traffic complex in the hygienic assessment of the quality of ambient air of megalopolises. To obtain objective information on the level of atmospheric air pollution, it is necessary to use the data base of ATCS on the intensity of traffic flow. The study of the ATCS functioning efficiency in seven cities of Russia showed its positive effect on increase of the traffic system capacity and decrease of the air pollution with exhaust gases. The ATCS activities provide the increase of average passing speed (22-23%), reduction of the area with the zone of increased wear of the road pavement (13-25%), cutting time of the traffic- light creep by 20-

45% and decrease of gasoline consumption -11-16%. Keuken et al.[11], concluded that on motorways speed management is an effective measure, while a low emission zone, is less effective to reduce health effects of road traffic emissions. For inner-urban roads reduction of traffic volume seems the most effective traffic measure for improving air quality and health. Currently, the existing monitoring system in the area of the main traffic arteries in the city of Kazan makes it impossible to correctly assess the vehicles' impact on the atmospheric air quality. The critical result of our study is taking into account of supplementary data on the traffic flow intensity in districts of the city, which enabled us to differentiate the long-term effects of the atmospheric air pollution with vehicles on the population health. The results of the analysis showed the necessity of shifting the time of the atmospheric air status control at the APOS by 1 hour, which can result in compliance with the sampling time to a peak of traffic flow. The use of ATCS data will allow decreasing the traffic-light creep up to 30% in peak periods and reducing the air environment pollution with exhaust gases. The necessity of determining the risk reduction efficiency with the account of economic factors will provide the basis for future studies. The primary goal of health risk analysis is obtaining and synthesizing of information on possible impact of the human habitat factors on his health status, which is necessary and sufficient for justification of the most optimal managerial decisions on elimination or decrease of risk levels, optimization of control and monitoring of exposure and risk levels. Nowadays the pollution of atmospheric air is one of the major consequences of negative anthropogenic impact on the environment. The system of changing the monitoring of the atmospheric air pollution with vehicles in residential districts with the account of data on the traffic flow intensity was proposed for the first time in the research. The indices of hazard and ecological risks for the population health were chosen as the major criterion for formation of the observation system within monitoring. The risk reduction can influence on the level of the project of modernization of the system for the atmospheric air pollution control and preventive measures. The most effective decisions as regards the risk reduction should be implemented

Acknowledgements

The work is performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

References

1. Zaitseva N.V., May I.V., Kleyn S.V., Goryaev D.V. Methodical approaches to selecting observation points and programs for observation over ambient air quality within social and hygienic monitoring and "pure air" federal project Health Risk Analysis. - 2019. Vol. 3, Pp. 4–17.
2. Stepanova N.V., Fomina S.F. Risks for Population Health from Atmospheric Air Pollution in the City of Kazan. *Proceedings*, Vol.6, №3, 2019. https: //doi.org/10.3390/IECEHS-1-05706 Accessed 26 March 2020
3. Zhang P., Dong G., Sun B., Zhang L., Chen X., Ma N. et al. Long-Term Exposure to Ambient Air Pollution and Mortality Due to Cardiovascular Disease and Cerebrovascular Disease in Shenyang (China)". PLoS ON. - 2011. Vol.6, № 6, e20827.
4. Guerreiro C.B., Foltescu V., Leeuw F. Air quality status and trends in Europe., Atmos. Environ. – 2014, Vol.98., Pp. 376–384.
5. Jandacka D., Durcanska D. Differentiation of Particulate Matter Sources Based on the Chemical Composition of PM10 in Functional Urban Areas. *Atmosphere*, Vol. 10, 2019. P. 583.
6. Rakhmanin Yu.A., Levanchuk A.V. Hygienic assessment of atmospheric air in areas with varying degrees of development of the road and automobile complex, *Gig Sanit*, vol. 95, № 12, 2019. Pp. 1117-1121.
7. World Health Organization (2016) Health risk assessment of air pollution – general principles, http://www.euro.who.int/ data/assets/pdf_file/0006/298482/Health-risk-assessment-air-pollution-General-principles-en.pdf?ua=1 Accessed 26 March 2020
8. Kelly F.J. Fussell J.C. Air pollution and public health: emerging hazards and improved understanding of risk. Environ. Geochem. Health. - 2015, Vol.37, Pp. 631–649.
9. Pant P., Harrison RM. Estimation of the Contribution of Road Traffic Emissions to Particulate Matter Concentrations from Field Measurements: A Review, Atmos. Environ. – 2013, Vol. 77. Pp. 78–97.
10. Jandacka D, Durcanska D (2019). Differentiation of Particulate Matter Sources Based on the Chemical Composition of PM10 in Functional Urban Areas. Atmosphere 10: 583. https:// doi:10.3390/atmos10100583
11. Keuken MP., Jonkers S., Zandveld P., Voogt M. Elshout van den S. Elemental carbon as an indicator for evaluating the impact of traffic measures on air quality and health. Atmos. Environ. - 2012. Vol. 61., Pp.1–8.
12. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H et al (2012). 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 2010. Lancet, 380: 2224–2260 https://doi.org/10.1016/S0140-6736(12)61766-8
13. Guidelines for health risk assessment for the population on exposure to chemical substances polluting the environment R 2.1.10.1920-04. Federal Center of the State Committee for Sanitary and Epidemiological Control, Moscow, 2004,143 p.
14. Lim T.E., Fridman K.B., Shustalov S.N. Model of study of health risk to the population caused by road transport contamination. Human ecology. - 2011. Vol. 8., Pp. 3–7.
15. Rak J., Pietrucha-Urbanik K. An approach to determine risk indices for drinking water – study investigation. Sustainability-Basel, vol. 11, № 11, 2019. p. 3189.
16. Stepanova N.V., Valeeva Emilia R. Main trends in children's population health in the Republic of Tatarstan. *Gig Sanit*, 2015. Vol. 94, № 1., Pp. 92-97.
17. Andreeva E.E., Shur P.Z., Klimenko A.R., Fokin V.A. Hygienic characteristics of the priority environmental media and risk assessment of their influence: a case study in Moscow city. Health Risk Analysis. - 2015, Vol. 4., Pp. 62-72.
18. Lim S.S., Vos T., Flaxman A.D., Danaei G., Shibuya K., Adair-Rohani H. et al. 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 2010. Lancet. - 2012. Vol 380, Pp. 2224–2260.