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Complex Sanitary and Hygienic Characteristics of the Quality of the Megacity Environment

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Abstract

The complex assessment of habitat factors that affect the level of sanitary-epidemiological well-being and health status of the population of Almaty city over the past 10 years is presented in this article. (**International Journal of Biomedicine. 2017;7(3):243-247.)**

Key Words: air quality • atmospheric pollution • maximum permissible concentration • harmful emissions

Abbreviations

API, air pollution index; **BOD**, biochemical oxygen demand; **IAP**, index of atmospheric pollution; **MPC**, maximum permissible concentration; **MPCad**, average daily MPC; **MR**, maximum repeatability; **SI**, standard index; **SP**, suspended particulates; **TPP**, thermal power plant.

Introduction

One of the most important scientific problems of our time, which is both theoretical, fundamental and applied, and lies at the intersection of a number of branches of science and practice, is the question of the possibility of and mechanisms for regulating the level of public health. One of these mechanisms, of course, is the improvement of the quality of the habitat. Ecological and hygienic problems associated with the intensive growth of cities and urban populations are among the significant phenomena of modern times. In large industrial cities, where production facilities of various profiles are concentrated, significant amounts of various chemical substances are simultaneously emitted into to the environment, among which is a high proportion of highly toxic compounds of toxicity classes 1 and 2.[1] The rapid growth of motor vehicles in megacities causes additional environmental risks to public health.[2-5] This problem is the most difficult in a modern metropolitan area, including territories with different levels and patterns of industrialization and varying population density, significantly differing in architectural and planning characteristics, transport load, remoteness from green areas, etc.[6] Almaty city can serve as a typical example of such a metropolis. To address the issue of prioritizing activities aimed at minimizing environmental risks in large urban agglomerations, it is necessary to identify all major sources of environmental pollution, including sources in the adjacent areas, in connection with the possibility of spatial distribution of pollution.

The aim of our study was to conduct a complex assessment of habitat factors that affect the level of sanitary-epidemiological well-being and health status of the population of the megalopolis.

Material and Methods

In accordance with the purpose of the work, we carried out hygienic studies of the state of the habitat of Almaty in general and in the administrative districts of the city. Almaty is currently a major administrative center; its territory is divided

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into 8 districts: the Alatausky, Almalinsky, Auezovsky, Bostandyksky, Medeusky, Zhetysusky, Nauryzbaysky and Turksibsky districts.

In the course of the scientific and technical program for the study, all districts of the city were selected, with the exception of the Nauryzbaysky district, since this district was included in the city boundaries only in July 2014.

To adequately assess the air quality in Almaty in general and in the city's territorial-administrative districts, the results of instrumental measurements of the leading atmospheric pollution for the period 2007-2016 were analyzed. The sources of the study were:

- Annual report form 8
- Annual statistical collections "Environmental Protection in Almaty city for 2007-2010 and 2011-2015
- Information bulletins on the environmental state of the Republic of Kazakhstan for 2010-2016
- Monitoring data of the Republican State Enterprise "Kazhydromet"

Analysis of the state of atmospheric air pollution included qualitative and quantitative data on emissions of harmful substances from various types of sources (stationary and mobile). We calculated the average annual, average daily and maximum single concentrations of priority pollutants at the sampling points. The level of atmospheric pollution was estimated according to complex index, IAP_5, which is based on the level of 5 atmospheric pollutants with the highest normalized values for MPC, taking into account their hazard class: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon monoxide (CO), phenol, and formaldehyde.

Results and Discussion

In recent years, deteriorating air basin quality in Almaty city has become a serious threat to human health. The city's atmosphere is polluted by emissions from various types of economic activities, including industry and transport.

For the period 2007-2016, the number of stationary sources (industrial enterprises, individual residential sector and TPP-2), which have harmful emissions, decreased by 22.4%. Their share in the total annual emissions of pollutants is 19.8%-21.6% of all stationary and mobile sources.

Consequently, the leading source of pollution is the exhaust gases of motor vehicles, the specific level of which is up to 80% of all emissions into the city air. The situation is aggravated by the large share of old cars with a service life of more than 10 years, the technical condition of which in most cases does not meet hygienic standards. The growth in the level of air pollutants is facilitated by the use of low-quality fuels and lubricants when servicing motor vehicles. Transport pollution of the atmosphere, according to its effects on the human body, is divided into toxic, carcinogenic and irritating. Class I air pollutants include CO, oxides of nitrogen, oxides of sulfur, hydrocarbons and lead. Benzo[a]pyrene (BaP), di- and trichloromethane, benzene, acetaldehyde and formaldehyde are carcinogens. Because of emissions at the level of breathing, these substances are much more dangerous than industrial and energy toxicants, which are dispersed by high smokestacks for considerable distances. Oxides of sulfur and hydrocarbons are irritants. The degree of influence on the human body of all of the above components of the exhaust gases of road transport depends on their concentration in the atmosphere and the duration of exposure.

All of the above toxicants are present in the atmosphere of the metropolis. Thus, the main air pollutants in Almaty, which determine the greatest contribution to environmental damage and health risk to the population, are NO_2, SO_2, CO, formaldehyde, BaP, lead and SP (dust, soot), average annual concentrations of which in the surface layer of the atmosphere exceed the MAC by 2-5 or more times, especially under unfavorable meteorological conditions. In the cold season of the year (the first quarter and the end of the fourth quarter), the level of all priority pollutants reaches its seasonal maximum. In January, the average monthly concentration of NO_2 reaches 5.1 MPC, CO - 3.4 MPC, SP - 1.2 MPC, and formaldehyde - 2.9 MPC (Table 1, Fig. 1).

The dynamics of the average monthly levels of atmospheric pollution in Almaty city (the frequency of exceeding MPCad) for 2013-2015 is shown in Fig. 1. In accordance with the data in Table 1, a high concentration of formaldehyde persisted in the second quarter; only in the hottest months of summer did it decrease, by 2.2 times. A similar pattern was observed in all the years of the study period.

Table 1.

The dynamics of the average monthly levels of atmospheric pollution in Almaty city (the frequency of exceeding MPCad) according to "Kazhydromet"

Variable	2014			2015								
	October	November	December	January	February	March	April	May	June	July	August	September
	Quarter IV			Quarter IV			Quarter II			Quarter III		
SP	0.9	0.8	0.3	1.1	1.2	1.0	0.9	0.9	0.8	1.2	1.3	1.3
NO_2.	1.4	1.4	2.6	3.1	3.3	3.5	2.7	2.5	2.7	2.4	2.4	2.2
SO_2	1.1	0.3	0.4	0.3	0.3	0.4	1.2	0.5	1.4	1.3	1.5	1.0
Formaldehyde	4.2	3.3	4.6	4.6	4.3	4.6	5.2	5.3	5.4	5.7	1.4	1.5
SI (in respect to NO_2)	7.9	5.6	11.8	8.7	9.3	8.7	4.9	4.6	4.8	4.6	4.0	2.9
MR. %	92.3	93.3	98.6	100.0	98.6	100.0	97.4	89.9	97.4	93.6	47.8	22.7

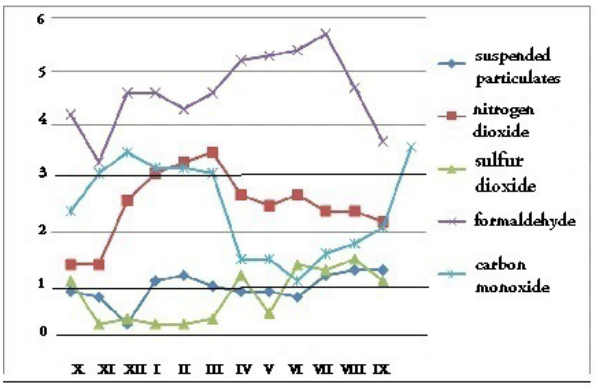

Fig. 1. *The dynamics of the average monthly levels of atmospheric pollution in Almaty city (the frequency of exceeding MPCad) for 2013-2015.*

Only for 2015, according to the data of the RSE "Kazgidromet" the number of cases of the MPC excess was 5,897 for CO_2, 2,970 for SO_2, 589 for NO_2, and 96 for SPs.

The highest rates were recorded for NO_2, belonging to the UN Class 2.3 substances—toxic gases. This gas exceeded the maximum one-time MPC by 11.76 times; 30,330 cases of excessive MPC were recorded. In 673 cases, it was more than 5 MPC and in 105 cases more than 10 MPC. According to the automatic observation post in Almaty, only in 2015 were there 105 cases of high air pollution. Indicators of air pollution were as follows: SI - 11.8, MR - 88.8%, which corresponds to very high degree of atmospheric air pollution – the fourth degree (SI>10, MR>50). The average annual IAP_5 in 2014 was 10.0.

The overall assessment of air pollution in 2015 showed a positive trend. In 2015, the atmospheric pollution indicators decreased compared to 2014: IAP_5 - 7.6 vs. 11.8, SI - 8.7 vs. 11.8, and MR - 47.8% vs. 88.8%. Despite this, the indicators characterizing the level of atmospheric pollution in the city are within the limits of a high level of contamination (IAP_5 within 7-13, SI>10, MR within 20%-49%). The air of the city remains the most polluted by nitrogen dioxide. In general, the average concentrations by pollutants were as follows: NO_2 - 2.6 MPC_{ad}, formaldehyde - 1.5 MPC_{ad}, and SO_2 - 1.2 MPC_{ad} The content of heavy metals and other pollutants did not exceed MPC.

IAP_5 in the metropolitan area for 2002-2015 was characterized by wavy dynamics (Fig. 2). After a rise in the level of atmospheric pollution in 2006-2008, the indicator fell down in 2011, then the growth was again recorded at 1.3 times: from 9.23 to 11.8.

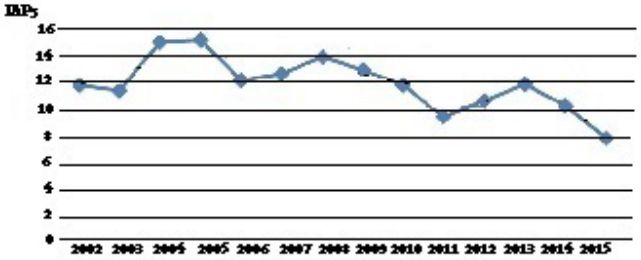

Fig. 2. *The dynamics of atmospheric pollution in Almaty city according to IAP_5 for 2002-2015.*

In the last three years of the study period, the indicator fell to 7.6 in 2015. On average, for the study period, the level of IAP_5 was 11.52±1.39, which corresponds to the third degree of atmospheric pollution. Although, the IAP_5 level exceeding 14 is considered dangerous for human life, in conditions of weak natural ventilation inherent to Almaty, these indicators reflect a direct negative impact on the health of the population and require urgent solutions.

A significant reduction in air pollution could be achieved by updating the vehicle fleet and more strict exhaust emission control. To solve the problems of optimizing traffic in the city, an important role is played by the construction of transport interchanges. Monitoring of air quality along the motorways after traffic interchanges were commissioned showed a decrease by more than 11% in the number of indicators of harmful substances exceeding MPC. This fact illustrates especially graphically the concentration of nitrogen dioxide in the ambient air in the area of traffic congestion (the intersection of Furmanov and Satpayev streets) and the area of the interchange (Furmanov and Al-Farabi streets) located two blocks to the south. The concentration of nitrogen dioxide in the first case was 8.94 MPC, which is almost 23 times higher than in the interchange area (0.39 MPC).

The territory of a large industrial city, such as Almaty, is not homogeneous in terms of its sanitary-hygienic situation. In this regard, the population living in various regions of the city is experiencing a different intensity of the impact of a variety of negative factors. The reasons for this lie in the varying degrees of the development of industrial production in the regions, the presence of thermal power plants and other sources of pollution, geographical location and the "rose of wind."

Data on the distribution of the amount of air pollutants from stationary sources in the districts of Almaty for the period 2007-2016 are presented in Table 2. Thus, the highest level of atmospheric pollution, on average, for 2007-2015 was observed in the Zhetysusky district (6516.14±1303.54 tons/year), which amounted to more than half (52.13%) of the average city level.

Table 2.

Rank distribution of Almaty districts by the amount of emissions from stationary sources for the period 2007-2015

Districts	Emission (tons/year)		Share of total urban emissions (%)	
	average level for the period	Rank number	average level for the period	Rank number
Alatausky	227.00±74.44	7	1.81±0.63	7
Almalinsky	683.29±110.23	6	5.46±1.32	6
Auezovsky	1694.71±735.52	3	13.55±6.15	3
Bostandyksky	713.29±104.00	5	5.70±0.68	5
Zhetysusky	6516.14±1303.54	1	52.13±7.11	1
Medeusky	770.43±138.11	4	6.16±1.15	4
Turksibsky	1913.28 ±339.48	2	15.30±1.44	2
Almaty city	12500.14±1104.21	-	100.00	-

According to the level of air toxins emitted from stationary sources, the studied districts ranged in the following order: the Zhetysusky (52.13±7.11%), Turksibsky (15.30±1.44%), Auezovsky (13.55±6.15%), Medeusky (6.16±1.15%), Bostandyksky (5.70±0.68%), Almalinsky (5.46±1.32%), and Alatausky (1.81±0.63%) districts. The lowest average indicator was recorded in the Alatausky district with a level of emissions of 227.0±74.44 tons/year (1.81%), which can be explained by the absence of large industrial enterprises in the area.

The main impact on the general air pollution of the Alatausky district, as well as the city as a whole, is caused by the emissions of the thermal power complex (TPP-2) located near the western border of the district. The main fuel used by TPP-2 is Ekibastuz coal with an ash content of 34.4%. With total emissions of 39.5 thousand tons per year, up to 15,642 tons of harmful substances are carried to the city's territory with winds from the north, west and northwest, which exceeds the volume of emissions from all stationary sources of the thermal power and industry enterprises located in the city territory. In addition, a significant part of the private sector that occupies a significant part of the territory of the Alatausky district is not gasified and is a source of solid fuel combustion products, which is confirmed by its exceeding by 1.2-1.6 times the MPC level of CO and by 11.2 times the MPC level of the dust in the air of the district in the cold season. With incomplete combustion and thermal decomposition of fuel hydrocarbons, suspended substances (soot) are formed, which are particles of solid carbon, on the surface of which BaP can be adsorbed. In this case, the deposition of soot particles on airway and alveolar surfaces has an even more negative effect on the body, stimulating the development of malignant neoplasms.

The leading causes of atmospheric air pollution from stationary sources are obsolete technologies of many industries, insufficient quantity and low efficiency of existing dust and gas cleaning installations, disturbances in the technological mode of operation, and the use of low-quality coals in power engineering. The rapid growth of the car fleet in megacities has led to an increase of more than 50% in the amount of harmful impurities in the air and an increase in the noise levels on urban highways by 5-10 dB. One of the negative characteristics of traffic noise is its spread over vast areas and almost constant impact throughout the day. Strong and prolonged noise has a harmful effect on the human body as a whole, causing irritation, deteriorating well-being and speeding up the fatigue growth process. The share of transport in the noise impact on the population of the Auezovsky and Medeusky districts, where large transport routes are located, reaches 80% and is 50-55 dB in the daytime and 40-45 dB at night.

The average values of gamma-ray background of the surface layer of the atmosphere along the metropolitan areas were in the range between 0.10 and 0.31 μSv/h. On average, the gamma-ray background was 0.16 μSv/h and was within acceptable limits.

In the territory of Almaty, there are 22 rivers and 4 riverbeds of artificial origin. The total length of riverbeds is 225.8 km. The total area of the water mirror is 1,116 hectares. The largest rivers are the Ulken Almaty (the length of 29 km), the Kishi Almaty (the length of 28 km) and the Esentai River (the length of 25 km). Monitoring of water resource quality at 3 water bodies in Almaty for 2013-2015 showed that no significant changes in the state of these water bodies were recorded during the 3-year period. During the observation period, the water temperature was in the range from 5.1 to 4.2ºC; the hydrogen index in all samples taken did not exceed 7.8. The concentration of oxygen dissolved in water ranged from 10.1 mg/dm^3 (the Kishi Almaty) to 11.1 mg/dm^3 (the Esentai River). BOD_5 was 1.5 mg/dm^3 and 1.4mg/dm^3, respectively. In the Ulken Almaty, similar indicators were in the range between 1.5 mg/dm^3 and 10.2 mg/dm^3. Excesses of MPC in water of all three water bodies were recorded for substances from groups of the biogenic substances (nitrogen nitrite - from 1.51 MPC to 1.9 MPC; fluorides did not exceed 1.1 MPC) and heavy metals. The copper level was 1.27-1.50 MPC. The highest levels of copper and manganese were recorded in the Kishi Almaty - 1.77 MPC and 2.3 MPC, respectively. These indicators were lower for the Ulken Almaty (copper - 1.27 MPC, manganese - 1.58 MPC) and the Esentay River (copper - 1.5 MPC, manganese - 1.35 MPC). In Lake Ulken Almaty, the water temperature was in the range from 5.1 to 8.3 ºC, the hydrogen index was 8.0; the concentration of dissolved oxygen in the water was 9.3 mg/dm^3 and BOD_5 - 0.4 mg/dm^3. Substances from the group of heavy metals exceeded MPC (copper - 1.3 MPC). Pollution of water bodies in Almaty by cadmium and zinc was minimal.

Thus, **in summary**, we made following conclusions from our analyses:

- In 2007-2015, the air pollution of the city was characterized as high and very high. During the follow-up period, the mean values of SI, MR and IAP_5 were 11.5±0.62, 88.8±4.2% and 11.5±0.91, respectively. In the dynamics of observation, there was a tendency to improve the situation in 2015: IAP_5 decreased by 1.55 times, SI - by 1.36 times and MR - by 1.86 times. Despite this, the studied indicators remained within a high level of contamination.

- Between 2007 and 2014, the number of stationary sources (industrial enterprises, individual residential sector and TPP-2) with harmful emissions decreased by 22.4%. Their share in the total annual volume of emissions of pollutants was 19.8%-21.6% of all stationary and mobile sources. Consequently, the leading sources of pollution are the exhaust gases of motor vehicles, which constitute about 80% of all air pollution.

- The main pollutants of Almaty's air, which determine the largest contribution to environmental damage and health risk to the population, are NO_2, SO_2, CO, formaldehyde, BaP, lead, and SP (dust, soot), whose mean annual concentrations in the surface layer of the atmosphere exceed MPC by 2-5 or more times, especially under unfavorable meteorological conditions. In the cold season of the year (the first quarter and the end of the fourth quarter), the level of all priority pollutants reaches its seasonal maximum. In January, the average monthly concentration of NO_2 reaches 5.1 MPC, CO - 3.4 MPC, SP - 1.2 MPC, and formaldehyde - 2.9 MPC. IAP_5 in

the metropolitan area was characterized by wavy dynamics for 2013-2015 with the expressed tendency to a decrease in 2015: 11.8 vs. 7.6 in 2014 with a negative rate of a gain (-) of 35.6%.

- According to the level of air toxins emitted from stationary sources, the studied districts ranged in the following order: the Zhetysusky (52.13±7.11%), Turksibsky (15.30±1.44%), Auezovsky (13.55±6.15%), Medeusky (6.16±1.15%), Bostandyksky (5.70±0.68%), Almalinsky (5.46±1.32%), and Alatausky (1.81±0.63%) districts.

- We found a steady increase in emissions of pollutants in the Auezov and Alatau districts with the greatest average daily concentrations of dust, NO_2 CO, and lead. Excesses of MPC by 1.2-1.6 times for CO and 11.2 times for dust in the air of the Alatau region testifies to the predominant use of solid fuel in the heat sources (low-quality coal, wood, household waste).

- The share of transport in the noise impact on the population of the Auezovsky and Medeusky districts, where large transport routes are located, reaches 80% and is 50-55 dB in the daytime and 40-45 dB at night.

Competing interests

The authors declare that they have no competing interests.

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