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ON ASSESSING THE MORBIDITY OF THE POPULATION ASSOCIATED WITH THE ATMOSPHERIC AIR QUALITY ON THE EXAMPLE OF A RUSSIAN CONSTITUENT ENTITY

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According to the World Health Organization (WHO), 24% of the global burden of diseases and 23% of all deaths associate with environmental factors. The presence of chemical impurities in the air can have an adverse effect on the health of the population. A connection has been established between the increased content of chemical impurities in the air and the development of such pathologies as diseases of the respiratory system, circulatory system, the formation of malformations, etc. Many countries implement projects to improve air quality. For the purpose of targeted development of management decisions aimed at minimizing the adverse impact of atmospheric air on the health of the population, the study of the morbidity of the population associated with the impact of priority atmospheric air hazard factors is relevant. The research goal is to characterize the morbidity of the population associated with air quality (on the example of Krasnoyarsk Krai) to identify the priority factors of atmospheric air that form the greatest contribution to the associated morbidity. The qualitative characteristics of the atmosphere and the level of morbidity of the population in Krasnoyarsk Krai are estimated on the basis of official data of federal and industry statistics. The analysis of the primary morbidity of the population, designated by the WHO as an indication of the effect of environmental factors, has been carried out. The authors calculate the number of third-party cases of diseases associated with the quality of the atmosphere and determine the priority risk factors. High proportions of air samples that do not meet the standards for the content of heavy metals, benz(a)pyrene, xylenes (59% of samples) have been registered over the territory of Krasnoyarsk Krai. Since 2012, there has been an increase of 0.2%–6.4% in the indicators of primary morbidity, indicated by the WHO as an indicator of the effect of environmental factors and a significant increase in congenital anomalies (the growth rate is 93.2%).

Up to 231 thousand third-party cases of diseases of the general population with diseases affecting the respiratory organs, circulatory system, hematopoietic organs, nervous system, eyes and their appendages determine the presence of aromatic hydrocarbons, nitrogen dioxide, hydroxybenzene (as well as its derivatives), benz(a) pyrene, nitrogen oxide, ammonia, dihydrosulfide and carbon disulfide, sulfur dioxide in the air in concentrations exceeding the standards. The most substantial number of diseases associated with air quality forms in the class of respiratory diseases (2020 – 587.4 cases per 100 thousand population, 64.5% of the total air-associated morbidity).

Keywords: *morbidity; exposure; chemicals; atmospheric air; pathology*

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К ВОПРОСУ ОЦЕНКИ ЗАБОЛЕВАЕМОСТИ НАСЕЛЕНИЯ, АССОЦИИРОВАННОЙ С КАЧЕСТВОМ АТМОСФЕРНОГО ВОЗДУХА, НА ПРИМЕРЕ СУБЪЕКТА РОССИЙСКОЙ ФЕДЕРАЦИИ

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С факторами окружающей среды, по оценкам Всемирной Организации Здравоохранения (ВОЗ), могут быть связаны 24% глобального бремени болезней и 23% всех смертей в мире. Присутствие химических примесей в воздухе может оказывать неблагоприятное влияние на состояние здоровья населения. Установлена связь между повышенным содержанием химических примесей в воздухе и развитием таких патологий как болезни органов дыхания, кровообращения, формирование пороков развития и пр. Многими странами реализуются проекты по улучшению качества воздуха. Для целей адресной разработки управленческих решений, направленных на минимизацию негативного воздействия атмосферного воздуха на здоровье населения, актуальность представляет изучение заболеваемости населения, ассоциированной с воздействием приоритетных факторов опасности атмосферного воздуха. Цель исследования – дать характеристику заболеваемости населения, ассоциированной с качеством воздуха (на примере Красноярского края), выявить

приоритетные факторы атмосферного воздуха, формирующие наибольший вклад в ассоциированную заболеваемость. Качественные характеристики атмосферы и уровень заболеваемости населения в Красноярском крае оценены на основе официальных данных федеральной и отраслевой статистики. Проведен анализ первичной заболеваемости населения, обозначенной ВОЗ в качестве индикации относительно действия факторов среды. Проведен расчет количества сторонних случаев заболеваний, ассоциированных с качеством атмосферы, определены приоритетные факторы риска. Над территорией Красноярского края зарегистрированы высокие доли проб воздуха, не соответствующих нормативам содержания тяжелых металлов, бенз(а) пирена, ксилолов (59% проб). С 2012 г. отмечен прирост на 0,2-6,4% показателей первичной заболеваемости, означенной ВОЗ в качестве индикатора относительно действия факторов среды, значимый прирост по врожденным аномалиям (уровень прироста – 93,2 %). До 231 тысяч сторонних случаев заболеваний общего населения болезнями затрагивающими органы дыхания, систему кровообращения, кровь и кроветворные органы, нервную систему, глаза и их придаточный аппарат определяет присутствие в воздухе аромо-углеводородов, диоксида азота, гидроксибензола (а также его производных), бенз(а)пирена, оксида азота, аммиака, дигидросульфида и сероуглерода, диоксида серы в концентрациях, превышающих нормативы. Наибольшее количество ассоциированных с качеством воздуха заболеваний формируется в классе болезней органов дыхания (2020 г. – 587,4 сл. на 100 тыс. населения, 64,5% от всей ассоциированной с воздухом заболеваемости).

Ключевые слова: заболеваемость; воздействие; химические вещества; атмосферный воздух; патологии

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Introduction

Russian and international relevant studies have established that the environment affects the health of the population. According to the World Health Organization (WHO), 24% of the global burden of diseases and 23% of all deaths associate with environmental factors [13].

Atmospheric air is an inhomogeneous complex mixture of gases, liquids, and solid particles that can affect the health of the population [10]. Atmospher-

ic pollution with carbon monoxide, suspended substances, ozone, heavy metal compounds, nitrogen dioxide, nitrogen oxide, can trigger the onset or exacerbation of an existing pathology of such diseases as cerebrovascular diseases, pneumonia, chronic obstructive pulmonary disease, influenza, osteoarthritis, asthma, peptic ulcer disease, neoplasms, circulatory system diseases, hypertension, diabetes mellitus, kidney diseases and rheumatism, pathologies of the neuroendocrine system, (12) congenital malformations [12; 14–16].

The consequence of the adverse aerogenic effect of atmospheric air pollution on the health of the exposed population is a significant burden of diseases and economic consequences for the country. Therefore, many countries, including the countries of the European Union and the Russian Federation, are taking measures to improve air quality [11]. Thus, the "Ecology" national project is currently being implemented in the Russian Federation, within the framework of which the "Clean Air" federal project has been created. The purpose of the latter is to improve the quality of the atmospheric air in the most polluted Russian cities. The project targets are to reduce the total volume of emissions of non-normative substances into the atmosphere by 20%, as well as reduce the number of large settlements with a high and very marginal level of atmospheric pollution.

In this context, studying the morbidity of the population in highly urbanized territories in connection with the influencing factors of atmospheric air, the establishment of priority pathologies and aerogenic factors that make the most substantial contribution to the associated morbidity is relevant and practically in demand.

The research goal is to characterize the morbidity of the population associated with air quality (on the example of Krasnoyarsk Krai), to identify priority aerogenic factors that form the most substantial contribution to the associated morbidity.

Materials and methods

Krasnoyarsk Krai is a priority region with an unfavorable situation in terms of atmospheric air quality on the basis of the government reports "On the state of sanitary and epidemiological welfare of the population in the Russian Federation" in 2012–2019 [4]. It also bases on the data from the Federal State Statistics Service on emissions of pollutants into the atmospheric air coming from stationary (2012–2018) and mobile (2012–2018) sources.

The quality of atmospheric air in the studied territory has been assessed on the basis of information from the departmental statistical reports of Rospotreb-

nadzor [6] (Form 18 "Information on the sanitary condition of the subject of the Russian Federation") for 2012–2020.

The analysis of morbidity has been performed using data on the primary morbidity of the population of the federal statistical collections entitled "Morbidity of the entire population of Russia with a diagnosis established for the first time in life" for 2012–2019. [3]. The analysis focuses on the types of morbidity designated by the WHO as an indicator for the impact of environmental factors [1]: diseases of the cardiovascular system (strokes, CHD), neonatal conditions, malignant neoplasms, chronic respiratory diseases, etc.

In addition to the WHO-designated indicator health disorders, an analysis of the indicators of primary morbidity of the population has been performed for all target organs and systems that are susceptible to the effects of chemicals present in the air of the territories of Krasnoyarsk Krai in quantities exceeding hygienic standards.

The calculation of additional cases of diseases of the population associated with the quality of atmospheric air has been carried out in accordance with Methodological Recommendations 5.1.0095-14 "Calculation of actual and prevented economic losses from mortality, morbidity, and disability of the population associated with the adverse impact of environmental factors" [5]. The models obtained on the basis of dynamic subject data (2012–2019) for the Russian Federation are used to calculate the number of associated cases of diseases in the territory of the analyzed Russian region.

To characterize the dynamics of changes in indicators of both actual and associated morbidity, an indicator of the growth rate has been calculated: for actual morbidity – 2019 to 2012, for associated – 2020 to 2012.

Results

On the Krasnoyarsk Krai territory, a decrease in the total amount of pollutants released into the atmospheric air from a hospital is recorded, the rate of decline in 2018 compared to 2012 is 10.2%, and from mobile sources is 33.2% (Fig. 1).

In dynamics (2012–2020), the share of atmospheric air samples with excess of standards in Krasnoyarsk Krai is decreasing: the rate of decline of the indicator for all samples is 24.4%. For specific substances, such as benz(a)pyrene, heavy metal compounds, xylenes, high proportions of air samples that have not met the standards are recorded during the analyzed period: samples for xylene – up to 59%, for benz(a)pyrene – up to 31%, for heavy metals – up to 21%.

For substances: sulfur dioxide, suspension of substances, lead compounds, hydrocarbons (also aromatic), hydroxybenzene and its derivatives, benzene,

ammonia, carbon monoxide, formaldehyde, there have been annual exceedances of the standards of content in atmospheric air.

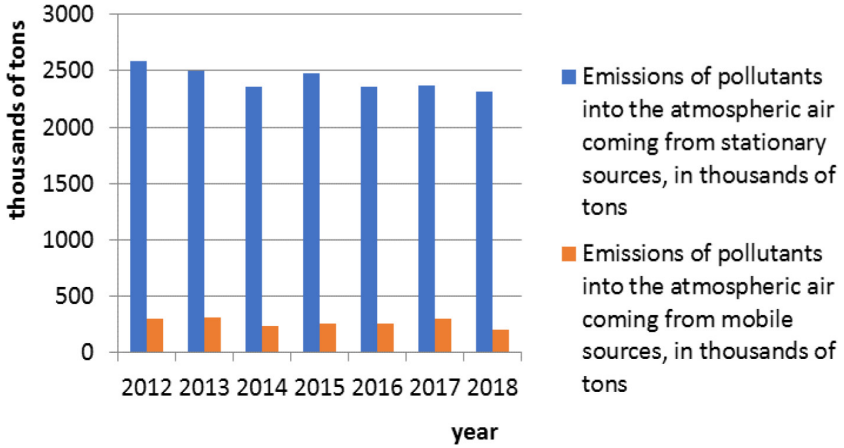

Fig. 1. Emissions of pollutants into the atmospheric air coming from stationary and mobile sources, 2012–2018, in thousands of tons.

The maximum values of the proportion of samples that do not meet the standards in some years for these substances reach 20% (aromatic hydrocarbons) (Table 1). The share of samples that do not meet the hygiene standards for the rest of the substances monitored at the posts is below 1%, or for most of the analyzed years, no excess of hygiene standards is recorded. Of all the substances for which excess of hygienic standards has been recorded in dynamics for 2012–2020, negative trends – an increase in the share of samples that do not meet hygienic standards – are noted for benz(a)pyrene, sulfur dioxide, benzene (the growth rate of indicators is 124.5%, 184.2%, and 41.9%, respectively).

The registered excess of the hygienic standards indicated in Table 1 of substances can have an adverse effect on the health of the population, in particular, on the immune system. It also includes the general development of the body, the respiratory system, the endocrine and cardiovascular systems, circulatory system, visual organs, central nervous system, kidneys, and liver.

The results of the analysis of morbidity, designated by the WHO as an indicator in relation to the impact of environmental factors, indicate that in the territory of the Krai for the analyzed period, an increase in the actually registered morbidity of the population at the primary stage of congenital

anomalies and malformations, deformities and chromosomal disorders, neoplasms, diseases of the circulatory system and respiratory organs has been noted: the growth rates of indicators are 93.2%, 6.4%, 2.4%, and 0.2%, respectively (Table 2).

Table 1.

List of pollutants for which excess of hygienic standards (Threshold limit value maximum single, Threshold limit value mean-diurnal) of their content in the atmospheric air of settlements (urban and rural) in Krasnoyarsk Krai, 2012–2020, in %, are registered

Polluting substance	The proportion of samples exceeding the Threshold limit value $_{\text{maximum single}}$, Threshold limit value $_{\text{mean-diurnal}}$, in %									Growth rate 2020 to 2012
	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Total	4.5	4.3	3.9	3.6	2.3	2.3	1.7	2.0	3.4	-24.4
Benz(a)pyrene	13.9	15.7	15.9	0.0	6.8	10.8	19.0	9.0	31.2	124.5
Heavy metals	9.0	18.0	14.8	21.2	13.8	15.6	0.3	0.2	0.2	-97.8
Xylene	59.0	1.4	4.8	6.7	11.0	0.0	1.0	0.7	19.0	-67.8
Lead compounds	3.6	8.2	11.6	16.7	9.3	9.1	0.2	0.0	0.4	-88.9
Aromatic hydrocarbons	20.0	1.4	4.7	0.7	2.9	0.6	1.2	0.9	13.0	-35.0
Hydrocarbons	18.0	1.7	3.7	1.0	2.4	0.6	1.0	0.8	10.6	-41.1
Suspended substances	5.4	5.7	4.5	0.8	2.6	1.2	6.3	3.1	1.3	-75.9
Sulfur dioxide	1.9	3.1	2.5	3.2	2.8	2.3	3.6	6.1	5.4	184.2
Benzene	3.1	0.4	4.5	0.3	0.7	0.7	1.3	1.8	4.4	41.9
Hydroxybenzene and its derivatives	2.1	0.4	2.8	0.2	1.3	0.6	1.7	1.4	0.7	-66.7
Carbon monoxide	4.7	0.1	0.2	0.1	0.4	0.4	0.4	1.1	0.4	-91.5
Formaldehyde	0.8	0.5	0.9	0.1	1.7	0.0	0.4	3.0	0.3	-62.5
Ammonia	0.0	0.0	2.7	0.0	5.0	0.7	0.0	0.2	0.2	-

In 2019, compared to 2012, there is a decrease in the indicators of primary morbidity of the entire population with diseases of the central nervous system, visual organs, liver diseases, the rates of decline of indicators are 14.7%, 21.7% and 4.1%, respectively. The incidence rates in 2019 are 1,549.8 $_{0/0000,}$ 3,584.7 $_{0/0000}$ and 69.8 $_{0/0000}$($_{0/0000}$– cases per 100 thousand of the population of the corresponding age). The indicator of the primary morbidity of the entire population with the pathology of the neuroendocrine system increased by 7.5%, amounting to 1,305.1 0/0000 in 2019).

Table 2.

Dynamics of indicators of primary morbidity of the total population of Krasnoyarsk Krai by classes, indicative of the impact of environmental factors, in $_{0/0000}$ 2012–2019 for diseases

Year	Class of diseases			
	Congenital anomalies (malformations), deformities and chromosomal disorders	Neo-plasms	Circulatory system diseases	Respiratory diseases
2012	53.2	1,481	3,265.4	29,522.4
2013	57.7	1,603.2	3,439	29,530.4
2014	72.6	1,615.2	3,284.7	28,552.2
2015	98.5	1,665.2	3,387.4	27,646.3
2016	90.6	1,592.2	3,660.2	28,975.4
2017	111.1	1,673.9	3,676.1	29,705.1
2018	96.7	1,552.6	3,742.9	29,438.2
2019	102.8	1,576.4	3,344.8	29,585.7
Growth rate 2019 to 2012	93.2	6.4	2.4	0.2

The analysis of additional cases of diseases of the entire population associated with the quality of the atmosphere demonstrate that the number of cases of diseases annually ranges from 9,763–231,559 cases, an average of 54,850 cases for the analyzed period. In 2020, the number of cases of the probability associated with the air quality is 910.9 $_{0/0000}$ (26,109 absolute cases, including child population – 2,364 $_{0/0000}$ (13,513 absolute cases), for the adult working-age population – 433.8 $_{0/0000}$ (7,151 absolute cases).

Particularly, the authors find that additional cases of morbidity of the entire population with respiratory diseases, including asthma and status asthmaticus, chronic unspecified bronchitis, circulatory system, hematopoietic organs, central nervous system, eyes and their appendage diseases, are associated with exposure to such chemical impurities present in the atmosphere as nitrogen dioxide and its oxide, hydroxybenzene and its derivatives, carbon disulfide, sulfur dioxide, aromatic hydrocarbons, ammonia, benz(a)pyrene, dihydrosulfide, chlorine (its compounds), carbon monoxide, formaldehyde, heavy metal compounds, and lead compounds.

In 2020 in the structure associated with the air quality in the incidence of the total population are dominated by the disease in the incidence of respiratory and 64.5%, CNS – 29.6% of the circulatory system – 3.1%, the hematopoietic organs and certain disorders involving the immune mechanism – 1.7%, eyes and their appendage diseases – 1.1% (Fig. 2).

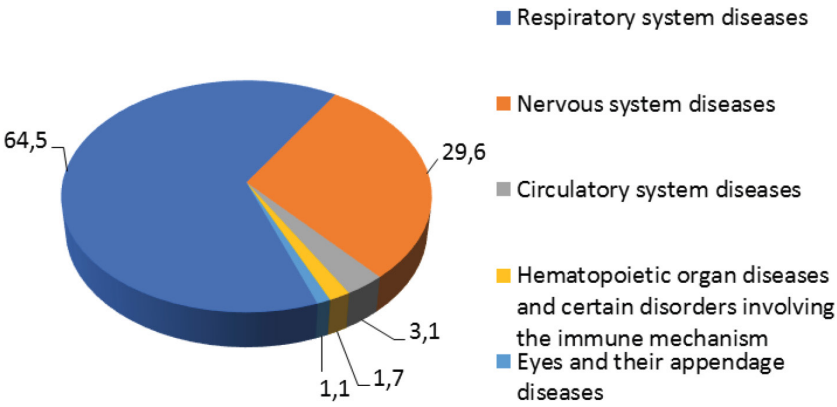

Fig. 2. Structure of the morbidity rate associated with the quality of atmospheric air of the entire population of Krasnoyarsk Krai in 2020, in %.

In dynamics, since 2012, there has been a decrease in the indicator of associated morbidity of the entire population with respiratory diseases, the rate of decline of the indicator in 2020 compared to 2012 is 53.8% (2020 – 587.4 $_{0/0000}$ or 16,836 absolute cases). Priority aerogenic factors for the formation of respiratory pathologies are hydroxybenzene and its derivatives, nitrogen dioxide, formaldehyde, nitrogen oxide, etc.

Adverse trends are noted in relation to the increase of the number of additional cases of asthma and status asthmaticus in the total population by two times (2012– 3.2 $^{0}/_{0000}$ or 91 absolute cases, 2020 – 6,5 $_{0/0000}$ or 188 absolute cases), the increase in incidence due to the adverse trend of aerogenic priority risk factors – growth samples of the atmosphere that do not meet the standards for sulfur dioxide, hydroxybenzene (derivatives), nitrogen oxide, and nitrogen dioxide. Simultaneously, the number of additional cases of chronic unspecified bronchitis, probabilistically associated with atmospheric air quality, decrease by 1.9 times in 2020 compared to 2012 (2020 – 180.9$_{0/0000}$ or 5,184 absolute cases, 2012 – 344.8$_{0/0000}$ or 9,786 absolute cases).

In dynamics, since 2012, the trend of decline in the incidence of the General population has been associated with diseases of the CNS (2020 – 269.0 $_{0/0000}$ or 7,735 absolute cases), circulatory system (2020 – 28,6 $_{0/0000}$ or 10,515 absolute cases) and hematopoietic organs and specific disorders involving the immune mechanism (2020 – 15.2 $_{0/0000}$ or 437 absolute cases), eyes and their appendage diseases (2020 – 9.8 $_{0/0000}$ or 280 absolute cases) – the attrition rate of performance is 48.9%, 91.6%, 92.4%, and 64.5% respectively. The decrease

in associated morbidity is probably due to an improvement in the quality of the atmosphere in terms of reducing the proportion of samples that do not meet hygienic standards for priority aerogenic risk factors: hydroxybenzene and its derivatives, sulfur dioxide, carbon oxide, formaldehyde, aromatic hydrocarbons, and heavy metal compounds, including lead compounds.

Discussion

The research results confirm and complement data of previously published studies [2; 7–9; 15]. For the formation of effective actions to minimize the adverse impact on the health of the population of atmospheric pollution, it is updated to conduct a targeted study of priority influencing factors, zones of their influence, risk contingents, and types of relevant health disorders. Such studies allow, among other things, one to perform predictive estimates of economic losses associated with environmental protection and prevention of diseases of the population, as well as to assess the effectiveness of costs [5]. The focus of further research in this area should be directed to studying the peculiarities of the influence of atmospheric pollution on the state of health in the context of gender and age groups, taking into consideration regional climatic and geographical features, etc. The formation of risk profiles of territories is also relevant, with the allocation of the specifics of the influencing risk factors and reflection on the part of the health of the population.

Conclusion. The research results indicate that there is a positive trend in Krasnoyarsk Krai of reducing emissions of pollutants (2012–2018) both from stationary sources by 10.2% and from mobile sources of pollution by 33.2%.

Simultaneously, high proportions of samples that do not meet the standards are registered annually for such substances as xylenes, benz(a)pyrene, heavy metals up to 59% of samples. These substances are specific for emissions of enterprises in the region. The share of samples with exceeding the standards for the content of benz(a)pyrene, sulfur dioxide, benzene is growing: the growth rate of indicators in 2020 compared to 2012 has grown from 41.9% to 184.2%. For the remaining monitored substances, a favorable trend is registered to reduce the proportion of samples that do not meet the standards.

The results of the assessment of the primary morbidity of the population with diseases designated by the WHO as indicative diseases in relation to the quality of the habitat indicate that an unfavorable trend in the growth of new cases of congenital anomalies and malformations is registered in the territory of the region (the growth rate of the indicator is 93.2%). Compared to 2012, there is an increase of 0.2%–6.4% in the incidence of neoplasms, circulatory system, and respiratory organs.

The research results show that the average for the analyzed period is approximately 54 thousand (9–231 thousand) third-party cases of diseases of the general population associate probabilistically with the presence in the atmosphere of hydroxybenzene (derivatives), sulfur dioxide, ammonia, benz(a) pyrene, nitrogen oxide and dioxide, dihydrosulfide, chlorine and its compounds, carbon disulfide, carbon monoxide, formaldehyde, aromatic hydrocarbons, heavy metal compounds (lead compounds) in concentrations exceeding the standards.

The significant number of diseases associated with the quality of the atmosphere forms in the classes of respiratory diseases (2020 – $587.4_{0/0000}$ or 16,836 absolute cases) and the nervous system (2020 – $269.0_{0/0000}$ or 7,735 absolute cases). Priority risk factors are hydroxybenzene and derivatives, nitrogen dioxide, aromatic hydrocarbons, lead compounds, carbon monoxide, formaldehyde, and nitrogen oxide.

The number of cases of diseases of all classes associated with the quality of the atmosphere (respiratory diseases, diseases of the nervous system, diseases of the circulatory system, hematopoietic organs, and individual disorders involving the immune mechanism, diseases of the nervous system, diseases of the circulatory system, eyes and their appendage diseases) has been decreasing since 2012. The rate of indicator decline is in the range from 48.9% to 92.4%.

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