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Original Empirical Research

Assessment of the Level of Air Pollution and Aerogenic Risk to the Health of the People of Novocherkassk

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Abstract

Introduction. Assessment of the level of urban air pollution and its impact on public health is a crucial scientific task. Ensuring the environmental safety of urban areas is impossible if the air quality does not meet the established standards. Despite well-developed methodologies for assessing the health risks of urban environments, the results of such research in the regional context are insufficient. Currently, almost half of the population of the Russian Federation lives in cities with high or very high levels of air pollution. Among these cities, Novocherkassk in the south of Russia was identified as one of the most polluted in the period from 2014 to 2021. This necessitates conducting scientific research to assess the health risks associated with atmospheric air pollution in Novocherkassk. The aim of this study was to evaluate the health risks posed to the population of Novocherkassk due to air pollution.

Materials and Methods. The study used data from annual reports on the state of air pollution in cities in Russia from 2014 to 2021, which were prepared by the Federal State Budgetary Institution "Voeikov Main Geophysical Observatory" [1]. The authors used literary methods and methods of mathematical and statistical analysis in their work.

Results. The level of atmospheric air pollution for the period from 2017 to 2021 reached dangerous values for public health. Suspended solids and carbon oxide contributed most to the risk of health problems. The values of the complex indicator *P*, estimated by average annual concentrations, showed that the level of atmospheric air pollution in Novocherkassk was 1.68 times higher than in the largest city in the region, Rostov-on-Don. The highest level of atmospheric air pollution in Novocherkassk was noted within Post II, located at the intersection of highways and close to the impact zone of industrial enterprises.

Discussion and Conclusion. The calculations showed that exposure to polluted atmospheric air could cause symptoms of chronic intoxication in 240–280 out of every thousand people. When the maximum concentrations of pollutants in the atmospheric air of Novocherkassk were reached, from 579 to 692 people out of a thousand residents might experience adverse reflex reactions. In light of the identified health risks from air pollution, it is recommended to increase the number of green spaces and establish two additional monitoring stations for atmospheric pollution: one in the city's residential area and one near the Novocherkassk GRES power plant in the Donskoy district.

Keywords: level of atmospheric air pollution, aerogenic risks to public health, non-carcinogenic effects, carcinogenic health risks, intoxication, acute and chronic effects

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[1] Yearbooks. 2014-2021. URL: http://voeikovmgo.ru/index.php (accessed: 23.05.2024). (In Russ.)

Оригинальное эмпирическое исследование

Оценка уровня загрязнения атмосферного воздуха и аэрогенного риска здоровью населения города Новочеркасска

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Аннотация

Введение. Оценка уровня загрязнения воздуха городской среды и обусловленного им риска здоровью населения является актуальной научной задачей. Как представляется, невозможно обеспечить экологическую безопасность урбанизированных зон, если качество воздуха в их пределах не соответствует установленным стандартам. Несмотря на хорошо разработанный методический аппарат, позволяющий оценить риск здоровью населения городской среды, результатов подобных исследований в региональном аспекте недостаточно. В то же время почти половина всех жителей Российской Федерации в настоящее время проживает в городах с высоким и очень высоким уровнем загрязнения воздуха. На юге России в число городов с наиболее загрязненной воздушной средой в исследуемый период 2014–2021 гг. был включен г. Новочеркасск, что и обусловило необходимость проведения соответствующих научных изысканий. Цель данного исследования — оценить показатели риска здоровью населения г. Новочеркасска, вызванного загрязнением атмосферного воздуха.

Материалы и методы. В работе использованы данные ежегодников о состоянии загрязнения атмосферы в городах на территории России за 2014–2021 гг., подготовленных в Федеральном государственном бюджетном учреждении «Главная геофизическая обсерватория им. А.И. Воейкова». В числе примененных авторами методов литературные, методы математико-статистического анализа.

Результаты исследования. Уровень загрязнения атмосферного воздуха за период 2017–2021 годов достигал опасных для здоровья населения значений. Наибольший вклад в риск нарушения здоровья вносят взвешенные вещества и оксид углерода. Значения комплексного показателя *P*, оцененного по среднегодовым концентрациям, показали, что уровень загрязнения атмосферного воздуха в г. Новочеркасске в 1,68 раза выше, чем в крупнейшем городе региона Ростове-на-Дону. Наибольший уровень загрязнения атмосферного воздуха г. Новочеркасска отмечен в пределах поста II, находящегося на пересечении автомагистралей и приближенного к зоне воздействия промышленных предприятий.

Обсуждение и заключение. Проведенные расчеты показали, что воздействие загрязненного атмосферного воздуха может вызвать симптомы хронической интоксикации у 240–280 человек из тысячи, при достижении максимальных концентраций загрязняющих веществ в атмосферном воздухе г. Новочеркасска от 579 до 692 человек из тысячи жителей могут испытать неблагоприятные рефлекторные реакции. В связи с выявленным опасным для здоровья населения загрязнением атмосферного воздуха рекомендуется расширение площади зеленых насаждений и создание двух дополнительных постов наблюдения за загрязнением атмосферного воздуха: в селитебной зоне города и вблизи Новочеркасской ГРЭС, в микрорайоне «Донской».

Ключевые слова: уровень загрязнения атмосферного воздуха, аэрогенные риски здоровью населения, неканцерогенные эффекты, канцерогенные риски здоровью, интоксикация, острое и хроническое действие

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Introduction. The quality of life and health of the population is related to environmental factors, particularly those caused by human activity. In the Russian Federation, 63.6% of the population experiences a significant impact on their health from various natural, environmental, and socio-hygienic factors[2].

For urbanized areas, the main factor causing such an impact is physical and chemical transformation of the lower atmosphere due to pollution. According to the World Health Organization (WHO), 99% of the global population lived in areas with high concentrations of air pollutants in 2022. Air pollution also caused premature deaths of about 7 million people worldwide in the same year. It is important to note that the analysis of the effects of environmental factors in Russia shows that about 70% of non-communicable diseases can be attributed to atmospheric air pollution [1].

[2] *On the State of Sanitary and Epidemiological Welfare of the Population in the Russian Federation in 2021.* State Report. URL: https://www.rospotrebnadzor.ru/documents/details.php?ELEMENT_ID=21796 (accessed: 20.04.2024). (In Russ.)

As practice shows, concentrations of pollutants that are dangerous to public health are often found in central parts of large cities and territories located near industrial facilities or transport routes. Therefore, the assessment of air pollution in these areas is still a pressing issue in the field of environmental research. A reliable way to measure air pollution is through the use of risk indicators that can help to determine the impact of pollution on public health. This approach allows for a comprehensive understanding of the scale of air pollution's impact on the population, which can complement the current Russian system for assessing effects of pollution on health.

Currently, slightly less than half of the total population of the Russian Federation lives in urbanized areas with high and very high air pollution[3]. The convenient transport location and the labor potential of Novocherkassk contributed to the formation of a diversified industrial complex that has a significant impact on the environment and public health. In 2021, Novocherkassk was added to the list of cities of the Russian Federation with the highest level of atmospheric air pollution [2]. Due to its status as a major production and logistics hub in the Rostov region, Novocherkassk is the focus of this study, as it has the highest level of air pollution among all cities in the region.

Most of large industrial enterprises in Novocherkassk are located in an industrial area, away from the historical city center along the floodplain of the Tuzlov River. The only exception is the Novocherkassk GRES, which is located near the Donskoy district, which was incorporated into Novocherkassk in 2004. In the eastern wind direction, the air from the Novocherkassk GRES flows into the city and pollutes the air. In the western and southwestern directions, it affects the air in the Donskoy district. It is important to note that the self-purification coefficient of the atmosphere in this area is 4.39 per year. This does not contribute to the dispersal of anthropogenic pollutants [3, 4]. This is due to the high frequency of meteorological events that lead to the accumulation of harmful substances to dangerous levels in the surface air. In addition, the amount of green space in the urban area of Novocherkassk only accounts for 44% of the recommended amount, which is not enough to effectively purify the air.

It seems to the authors that there has not been a comprehensive assessment of surface air pollution in urban areas recently. Only in 2017, three stationary monitoring stations for surface air quality began operating here, and before that, route observations were the only method used to monitor the air quality within the city. This study aims to assess the health risks posed to the population of Novocherkassk due to pollution of the upper layers of the atmosphere.

To achieve this goal, we have carried out the following tasks:

1. We have assessed the level of air pollution in the city.

2. We have calculated numerical values of coefficients and indices related to non-carcinogenic effects on public health in acute and chronic situations.

3. We have conducted calculations of public health risks caused by chronic intoxication and the immediate effects of various pollutants.

4. We have identified the contribution of pollutants to the formation of public health indicators.

Materials and Methods. The study was based on data from stationary air pollution monitoring posts operated by the Federal State Budgetary Institution “North Caucasus Department of Hydrometeorological Service”. These posts collected data on the concentrations of various airborne pollutants in Novocherkassk between 2017 and 2021 [5]. Three of these posts were operational in Novocherkassk since 2017. They were designated as Posts I, II, and III in the study. Post I was located in the city center, at the intersection of major highways. Post III was in the area influenced by industrial enterprises. Post II was also in the impact zone of industrial activity, but was located at an intersection of highways as well.

Due to the insufficient number of monitoring posts for atmospheric air pollution, it was recommended to create two additional posts, one of which, conventionally designated as Post 1, should to be placed in a residential area on Petrovskaya Street, 1. To monitor atmospheric air pollution near Novocherkasskaya GRES, it was proposed to create a post in the Donskoy district, conventionally designated as Post 2. The existing stationary monitoring posts for atmospheric air pollution (designated as numbers I, II, and III) and recommended for monitoring the city's air quality (designated as numbers 1 and 2) are shown in Figure 1.

In order to achieve the goal of the study, we calculated the multiplicity of the average annual and maximum single concentrations of airborne pollutants analyzed, which corresponded to the maximum allowable hygienic standards. We also calculated the level of outdoor air pollution using indicator P[4].

Calculation of indicator P was carried out according to formula:

$$P = \sqrt{\sum K_I^2}, \quad (1)$$

where, K — multiplicity of exceeding the MPC of substances of various hazard classes reduced to the third class.

[3] *On the State and Environmental Protection of the Russian Federation in 2021.* State Report. URL: https://www.mnr.gov.ru/docs/gosudarstvennye_doklady/gosudarstvennyy_doklad_o_sostoyanii_i_ob_okhrane_okruzhayushchey_sredy_rossiyskoy_federatsii_v_2021_/?ysclid=lwoteqy14b321565566 (accessed: 19.04.2024). (In Russ.)

[4] *Guidelines for Assessing the Risk to Public Health from Exposure to Chemicals that Pollute the Environment.* R 2.1.10.192–04. URL: https://docs.cntd.ru/document/1200037399 (accessed: 28.03.2024). (In Russ.)

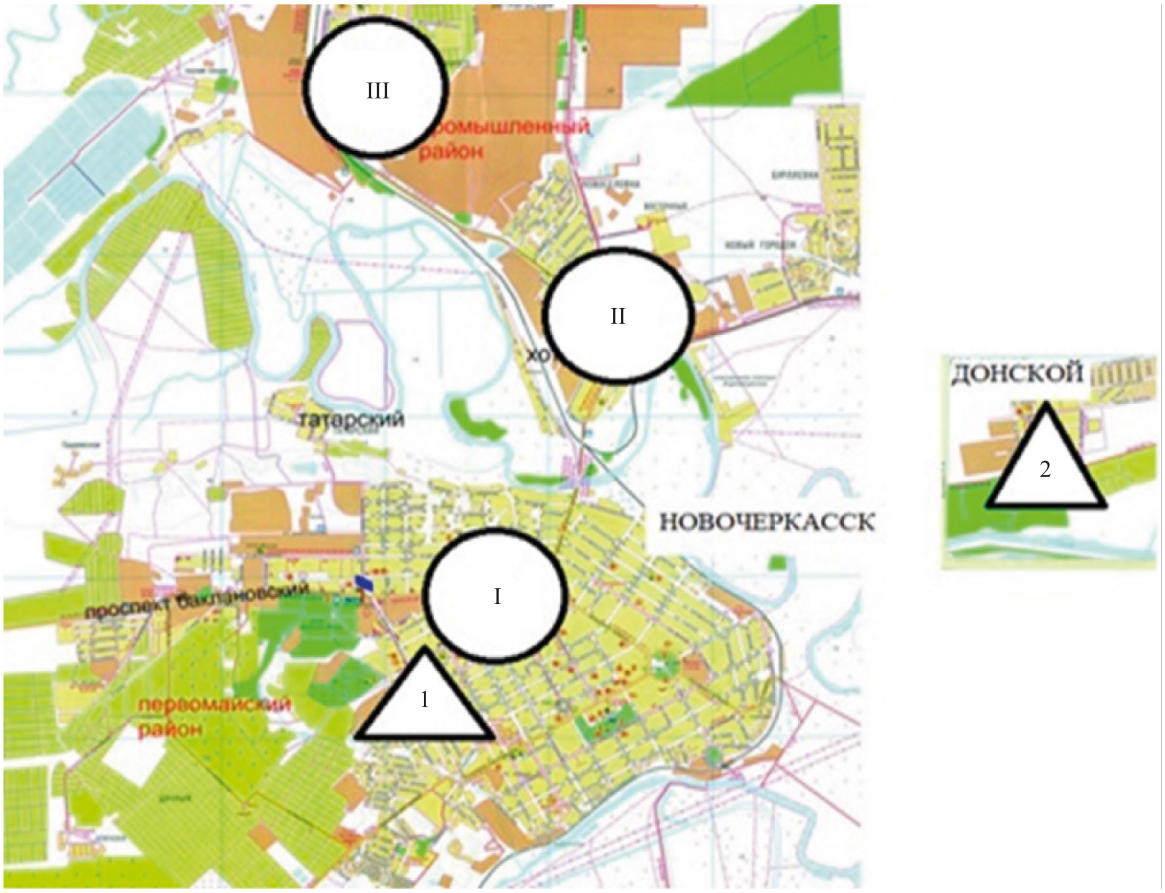

Fig. 1. Monitoring posts for atmospheric air pollution in the city of Novocherkassk[5]

The choice of non-carcinogenic effects as risk indicators was determined by the list of harmful substances of non-carcinogenic action[6], the concentrations of which were monitored at stationary monitoring posts for atmospheric air pollution in Novocherkassk.

The method of calculating coefficients and indices of non-carcinogenic effects in chronic and acute exposure was used as the main method of risk assessment [6, 7]. As an additional procedure, the risks of chronic intoxication and immediate action were determined[7].

Results. Increased emissions from motor vehicles and industrial enterprises led to dangerous air pollution in Novocherkassk. Thus, from 2017 to 2021, the average annual concentrations of suspended solids, nitrogen dioxides, carbon oxides, formaldehyde were exceeded, which have both carcinogenic and non-carcinogenic effects on public health. At the same time, the greatest multiplicities of exceeding the average daily MPC over the studied period of time were revealed for average annual concentrations of suspended solids (from 1.8 to 6 MPC), formaldehyde (from 0.7 to 2.7 MPC), nitrogen dioxides (from 0.4 to 2.2 MPC), carbon oxides (from 0.63 to 2.17 MPC).

It is important to note that the greatest multiplicities of exceeding of the maximum single MPC were also detected in the case of suspended solids and carbon monoxide, amounting to 2.0–13.2 MPC and 1.25–10.0 MPC, respectively. The excess of MPC of formaldehyde in the surface air of the city reached 1.44–3.74, nitrogen dioxide — 0.45–1.85. The average annual and maximum single concentrations of sulfur dioxide and nitrogen oxides during the studied time interval, as shown by the conducted studies, did not exceed the values of the corresponding MPC.

Based on the average annual concentrations of the substances assessed, we calculated the values of complex parameter *P*, which ranged from 4.0 to 5.0 over the specified period. This allowed us to conclude that there was a dangerous level of surface air pollution.

Calculations of parameter *P*, based on the maximum single concentration of the substances studied in this work, revealed a worrying level of contamination of the surface layer, since the values of parameter *P* were 22.0–28.5.

[5] *Ecological Bulletin of the Don.*URL: https://xn--d1ahaoghbejbc5k.xn--p1ai/about/projects/all/19/?ysclid=lwotyc7mh7723274679 (accessed: 28.03.2024). (In Russ.)
[6] R 2.1.10.192-04. *Guidelines for Assessing the Risk to Public Health from Exposure to Chemicals that Pollute the Environment.* Electronic fund of legal and regulatory documents. URL: https://docs.cntd.ru/document/1200037399 (accessed: 28.03.2024). (In Russ.)
[7] *Cancer.* World Health Organization (April 21, 2024). URL: https://www.who.int/health-topics/cancer#tab=tab_1 (accessed: 28.03.2024).

Within the limits of Post II, the highest values of parameter *P* were identified, estimated by the average annual and maximum single concentrations of pollutants considered in this study. As shown by the analysis of values of risk indices of chronic exposure calculated in the work, depending on the location of the observation post, their values varied from 33.5 to 37.1. The range of values of the acute exposure index was 15.9–22.6.

According to medical statistics, the respiratory system was the most vulnerable to acute and chronic health effects. The proportion of respiratory disorders ranged from 38.22% to 42.37%. The contribution of the above-mentioned threats and failures in the human respiratory system to the overall level of the acute exposure index reached maximum values — from 45.47 to 49.81%. Therefore, it was obvious that the increased level of pollution of the surface air layer posed a greater risk of acute exposure, which was consistent with both theoretical models and practical observations.

The value of the total risk of chronic intoxication varied depending on the location of the observation post — from 0.24 to 0.28. The risk level of chronic intoxication, as calculations showed, was mainly formed due to concentrations of suspended solids, the contribution of which caused a wide range of values (from 35.27 to 47.81%) depending on the location of the observation post of the atmospheric environmental monitoring network. Significant values of maximum risk for individual impurities led to high levels of the total risk from pollutants identified in the studied composition

It is interesting to note that within observation Posts I and II located near highways, the value of the total risk of immediate action was significantly influenced by the maximum risk level in terms of suspended matter concentrations, reaching values of 0.58 and 0.69, respectively.

Near Post III, high concentrations of carbon monoxide, causing a significant level of maximum risk, led to an increase in the total risk values to 0.58.

The air pollution analysis results in Novocherkassk were compared to data from the monitoring of surface air pollution in Rostov-on-Don of the same range of pollutants for the period from 2017 to 2021.

The assessment of air pollution levels in Rostov-on-Don was based on the analysis of data collected from three air pollution monitoring stations located in different parts of the city by the Federal State Budgetary Institution “North Caucasian Department of Hydrometeorological Service” (Posts 51, 52, 55), which had the most representative spectrum of substances taken into account [8].

Thus, Post 51 was located in the central part of Rostov-on-Don, at the intersection of highways with heavy traffic; Post 52 was close to the location of industrial enterprises; Post 55 was located in the residential area of the city.

Table 1 presents the results of the comparative assessment of the levels of air pollution in urbanized and industrial territories of Novocherkassk and Rostov-on-Don for 2017–2021. Indicators illustrating the level of air pollution turned out to be more than 1.5 times higher in Novocherkassk than in Rostov-on-Don.

In Rostov-on-Don, the contribution of suspended solids to the immediate health risk was 24% higher than in Novocherkassk. However, in Novocherkassk, the contribution of carbon oxide concentration to this type of risk was 2.5 times more significant than in Rostov-on-Don [9].

Table 1

Assessment of atmospheric air pollution levels in Novocherkassk and Rostov-on-Don

Indicator	Novocherkassk	Rostov-on-Don
P parameter for average annual concentrations	4.42	2.63
P parameter for maximum concentrations	24.59	23.52
Hazard index for chronic exposure	35.70	24.34
Hazard index for acute exposure	19.47	20.94
Risk of chronic intoxication	0.25	0.18
Risk of immediate action	0.61	0.53

The results of the assessment of contributions of various airborne pollutants to the risk of immediate action are presented in Figures 2 and 3.

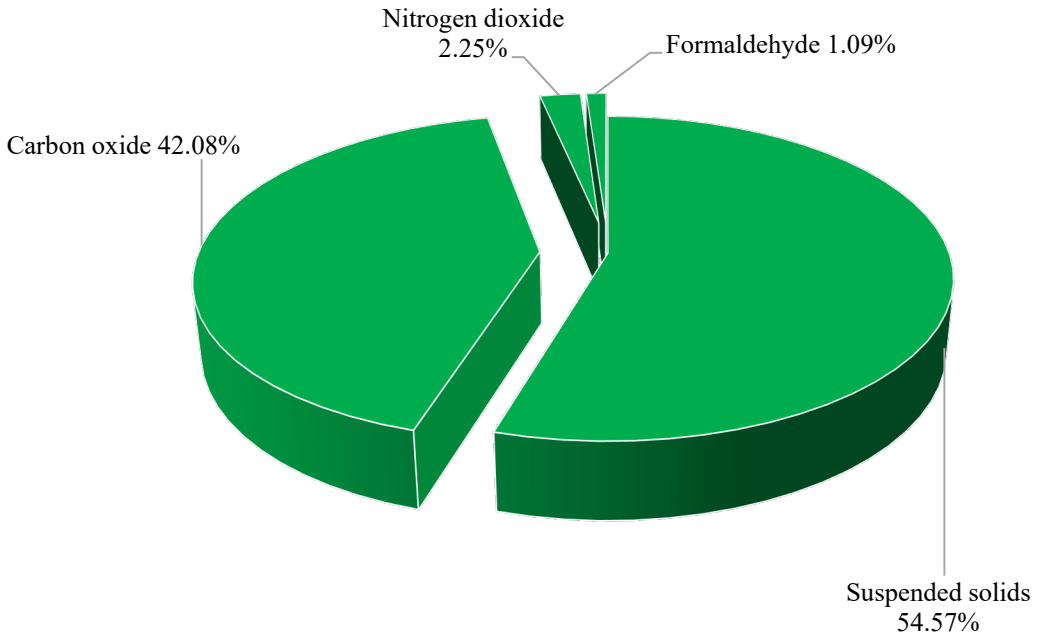

Fig. 2. Contribution of pollutants to the risk of immediate health effects for the population of Novocherkassk

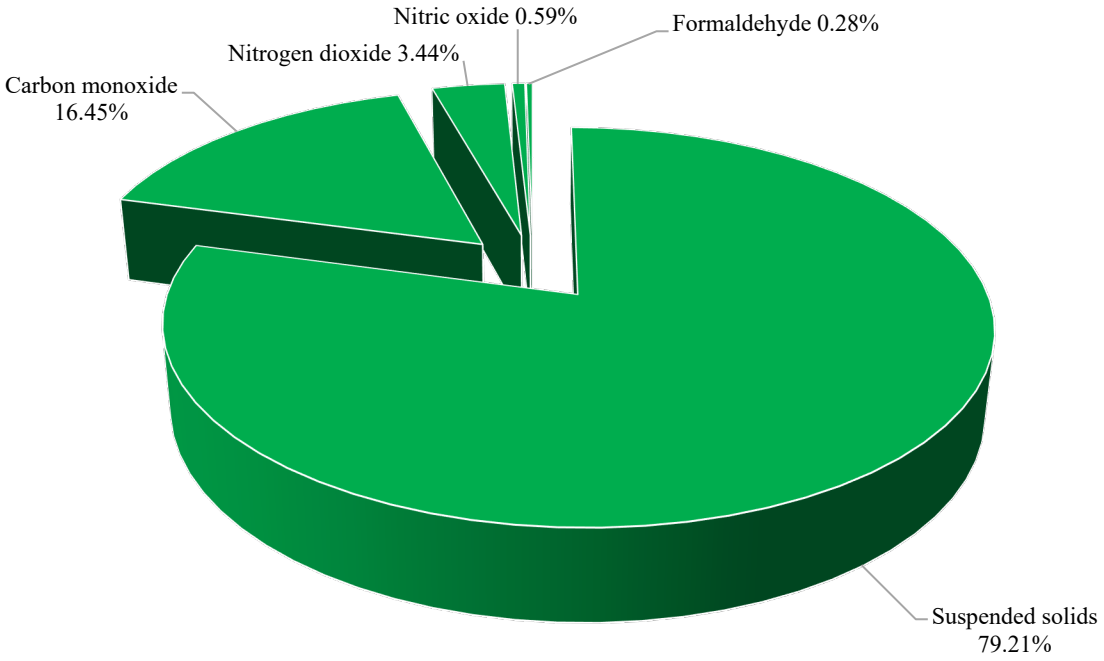

Fig. 3. Contribution of pollutants to the risk of immediate health effects for the population of Rostov-on-Don

Meanwhile, there were no significant differences between these two cities in terms of the contribution of pollutants to the risk of chronic intoxication.

Discussion and Conclusion. The calculations and analysis of the findings in this study reveal that the level of surface air pollution in Novocherkassk, which is harmful to public health, is caused not only by the significant emissions from industrial plants and vehicles but also by a combination of such natural and human-made factors as insufficient rainfall against the backdrop of frequent meteorological conditions that facilitate the accumulation of human-made pollutants in the surface layer, with a decrease in the proportion of green spaces, including urban forests and park areas [10].

Among the most significant results of the study are the following:

1. The state of the surface air layer within Novocherkassk is unfavorable, since the established pollution levels exceed permissible sanitary and hygienic standards. The highest danger to the health of the city's population is posed by suspended solids and carbon oxides in the surface layer.

2. The analysis of the results of calculations of indicator *P* within Novocherkassk allowed us to establish a dangerous level of air pollution. At the same time, the accumulation of pollutants in the atmosphere of Rostov-on-Don was assessed as causing concern.

3. Exposure to polluted air can lead to symptoms of chronic poisoning in 240 to 280 out of every thousand people. When maximum concentrations of pollutants are reached, 579 to 692 residents may experience adverse reactions.

4. The most significant concern is the pollution of air space in Novocherkassk, particularly within the boundaries of Post II, which is located at the junction of highways and near the impact zone of industrial enterprises.

5. Due to the dangerous level of atmospheric air pollution, it is recommended to expand the area of green spaces and create two additional monitoring posts for atmospheric pollution: in the residential area of the city and near Novocherkassk GRES, in the Donskoy district.

References

1. Rakhmanin YuA, Mikhaylova RI. Environment and Health: Priorities for Preventive Medicine. *Hygiene and Sanitation.* 2014;93(5);5–10. (In Russ.)

2. Andreev SS. *Integral Assessment of Climatic Comfort on the Example of the Territory of the Southern Federal District of Russia.* Saint Petersburg: Russian State Hydrometeorological University; 2011. 302 p. URL: http://elib.rshu.ru/files_books/pdf/rid_23963a035bf3491da5cc5a42d941e7d6.pdf (accessed: 23.05.2024). (In Russ.)

3. Kiselev AV, Shcherbo AP, Kislitsin VA, Novikov SM. Comparative Analysis of Methods for Calculating the Average Inhalational Exposure Loads in the Assessment of Health Risk. *Hygiene and Sanitation.* 2006;1;42–44. (In Russ.)

4. Shcherbo AP, Meltser AV, Kiselev AV. *Assessment of the Risk of the Impact of Production Factors on the Health of Workers.* St. Petersburg: Tertsiya; 2005. 115 p. URL: https://search.rsl.ru/ru/record/01002854973 (accessed: 23.05.2024). (In Russ.)

5. Andreeva ES, Klimov PV, Shtenske KS. Atmospheric Air Pollution as One of the Factors of the Non-Carcinogenic Risk to Human Health in Rostov-on-Don. *Geography and Natural Resources.* 2021;42(1):42–48. https://doi.org/10.15372/GIPR20210105 (In Russ.)

6. Klimova DN, Andreeva ES. Optimization of the Monitoring System of Atmospheric Air Pollution in Ensuring the Environmental Safety of Large Cities. *Advances in current natural sciences*. 2023;6:40–46. https://doi.org/10.17513/use.38051 (In Russ.)

7. Seleguei TS. *Development of an Improved Integrated Meteorological Measure the Scattering Power of the Atmosphere*. Otchet o nauchno-issledovatel'skoj rabote po teme 1.43.15. Novosibirsk: FGBU SibNIGMI, 2014. 131 p. (In Russ.)

8. Wild CP, Weiderpass E, Stewart BW (Eds.). World Cancer Report: Cancer Research for Cancer Prevention. 2021. URL: https://shop.iarc.fr/products/world-cancer-report-cancer-research-for-cancer-prevention-pdf

9. Denisov OV, Bulygin YuI, Ponomarev AE, Ponomareva LA, Lebedeva VV. Innovative Solutions Shockproof Protection in Occupations Associated with an Increased Risk of Injury. *IOP Conference Series: Earth and Environmental Science*. 2017;50(1):012044. https://doi.org/10.1088/1755-1315/50/1/012044

10. Bulygin YuI, Zharkova MG, Alekseenko LN. Aerodynamical Probation of Semi-Industrial Production Plant for Centrifugal Dust Collectors' Efficiency Research. *IOP Conference Series: Earth and Environmental Science*. 2017;50(1);012002. https://doi.org/10.1088/1755-1315/50/1/012002

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Заявленный вклад авторов:

П.В. Климов: обсуждение основной концепции и полученных результатов, доработка текста, выводов.

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