

Dynamic Analysis of Atmospheric Air Quality and Its Impact on Public Health

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ABSTRACT

The article presents the results of the dynamic analysis of the atmospheric air quality in the Russian Federation over the past 20 years and the assessment of additional associated morbidity of the population. The results indicate that air pollution levels capable of forming health disorders are systematically declining: share of non-standard samples decreased by 10.5 times and amounted to 0.6 % in 2019, for priority substances it decreased by 3.9–12.9 times and amounted to 1.03–4.83 %. As a result, the additional morbidity associated with air quality has decreased by 2.1 times (in 2019 it was 600.0⁰/₀₀₀₀ for all reasons). Respiratory diseases make up the bulk of the structure (69.4 %). More than 20 chemical components are priority risk factors. The unacceptable levels of acute and chronic non-carcinogenic risk were formed in all 12 priority cities (up to 5.39 HI and 24.1 HI respectively). There were 3 cities (Nizhny Tagil, Novokuznetsk, and Norilsk) with unacceptable carcinogenic risk levels: up to 2.92×10^{-3} for adults and 2.72×10^{-3} for children. Among the 12 most polluted cities, the largest number of associated diseases of the entire population was formed in Krasnoyarsk, Chelyabinsk, Magnitogorsk (39.000 – 51.200 cases), with relative indicators, in Magnitogorsk, Bratsk, Krasnoyarsk (4.670–9.400 cases per 100 000 people). The greatest contribution was due to respiratory diseases, accounting up to 96.8 %, to circulatory diseases, accounting up to 38.1 %, and digestive diseases, accounting up to 94.9 %.

Keywords: atmospheric air quality, monitoring, hygienic analysis, health risk, associated diseases

1. INTRODUCTION

At the current stage in the Russian Federation, air pollution issues are extremely topical and require administrative decisions at the federal and regional levels. The federal project "Clean Air" currently implemented in the country focuses on solving the set of these problems and reducing air pollution with an account of regional specifics and minimizing the risk and harm to public health [1, 2]. Air pollution from stationary and mobile sources is typical for most regions of the country. Waste from industrial and agricultural production, combustion of fuel by motor vehicles, production of heat and electricity, harmful emissions from city-forming enterprises, cattle and poultry farms have become threatening due to ongoing chemical pollution. Many technical solutions and modern technologies include the development and use of new chemical components, which currently do not have a complete description, and therefore pose new threats and may have potentially negative effects on human health [5, 6, 12, 15]. Numerous foreign and domestic studies demonstrate the negative impact of polluted air at acute and chronic, including multi-component, health effects [3, 4]. The specifics of air pollution and the sanitary and epidemiological situation in the regions determine the medical and demographic losses associated with the state of the environment.

According to WHO, environment quality accounts for about 15–25 % of the global disease burden. The priority risk factors contributing to additional morbidity and mortality associated with environmental factors include permanent and multicomponent air pollution among other factors [7, 8, 16].

Research of influence on changes in quality of air environment of both urban and rural territories remains actual due to dynamic change of structure and volumes of pollutants emissions, presence of regional features of spatial distribution of impurities, including climatographic characteristics, economic development of territories, level of realized compensatory nature protection and medical and prophylactic measures, etc. [1].

In this regard, the assessment of the air quality of inhabited areas is the basis for making administrative decisions and developing action plans to reduce air pollution, minimize risk and harm to public health [2, 17].

2. METHODS AND MATERIALS

The work aims to perform a hygienic analysis of air quality in the Russian Federation over the past twenty years, identify the main reasons for its change and priority risk factors, calculate additional cases of diseases associated with air quality in the regions of the Russian Federation and in the country as a whole.

Hygienic assessment of the air quality was based on the data from the departmental statistical reports of Rospotrebnadzor (Form No. 18 "Information on the sanitary state of the constituent entity of the Russian Federation", data from the federal information fund of social and hygienic monitoring) for 2000–2019. The study analyzed data on more than 40 monitored chemicals that pollute the air: nitrogen dioxide, nitrogen oxide, acrylates, aliphatic unsaturated hydrocarbons, aliphatic saturated hydrocarbons, amines (aliphatic and aromatic, dimethyl formaldehyde, etc.), ammonia, aromatic hydrocarbons, benzene, benz(a)pyrene, suspended solids, suspended particles (PM2.5 and PM10), hydroxybenzene and its derivatives, dihydrosulfide, cadmium, xylene, maleic anhydride, manganese, arsenic, pesticides, polychlorinated biphenyls, propanol, mercury, lead, sulfur dioxide, sulfuric acid, carbon disulfide, synthetic fatty acids, toluene, heavy metals, carbon oxide, formaldehyde, phthalic anhydride, fluorine and its compounds (in terms of fluorine), hydrogen fluoride, chlorine and its compounds, hydrogen chloride, ethanol, ethyl acetate, ethylbenzene, etc.

We calculated risk parameters according to R 2.1.10.1920-04 "Guidelines for the Assessment of Public Health Risk from Exposure to Polluting Chemicals" [9].

We calculated the number of health violations associated with the air quality according to MR 5.1.0095-14 "Procedure for Calculation of Public Health Violations Associated with the Negative Impact of Environmental Factors and Cases Prevention by Rospotrebnadzor Actions" [10].

The definition of priority chemical components proceeded from the results of hygienic assessing the proportion of non-standard samples of contaminants and the contribution of chemical components to the formation of associated diseases in the Russian Federation.

For the 12 most polluted cities from 10 subjects of the Russian Federation, included in the federal project "Clean Air", we assessed the inhalation risk to public health and calculated additional cases of diseases associated with air quality according to monitoring studies for 2012–2019 [13]: Bratsk (Irkutsk region), Krasnoyarsk (Krasnoyarsk region), Lipetsk (Lipetsk region), Magnitogorsk (Chelyabinsk region), Mednogorsk (Orenburg region), Nizhny Tagil (Sverdlovsk region), Novokuznetsk (Kemerovo region), Norilsk (Krasnoyarsk region), Omsk (Omsk region), Chelyabinsk (Chelyabinsk region), Cherepovets (Vologda region), Chita (Zabaikalsky region).

3. RESULTS

Hygienic indicators of air quality in populated areas of the Russian Federation have significantly improved over the last twenty years (2000–2019). The share of atmospheric air samples with an excess of hygienic standards for this period decreased by 10.5 times, including in urban areas – by 10.7 times, in rural settlements – by 5.3 times, and made 0.6 % in 2019 (0.59 % for urban and 0.53 % for rural settlements) (Figure 1).

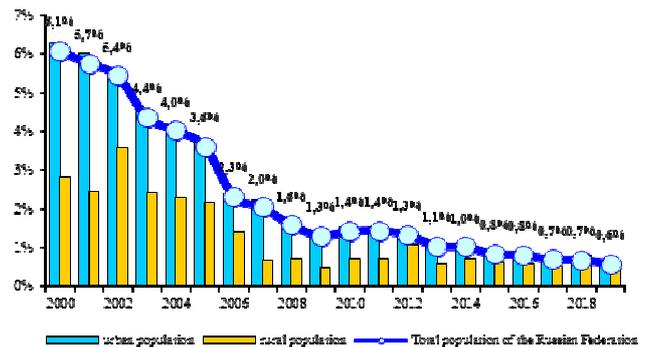


Figure 1 Specific gravity (%) of atmospheric air samples exceeding MAC in urban and rural settlements of the RF

Hygienic analysis of priority pollutants in 2000 and 2019 showed that in 2019 the list includes 4 substances from 10 priority pollutants monitored in 2000: benz(a)pyrene, suspended solids, carbon oxide and hydroxybenzene. For these substances there was a significant decrease in the share of atmospheric air samples exceeding hygienic standards by 3.9–12.9 times and made 1.03–4.83 %.

The analysis of the reasons for the dynamic reduction in the specific gravity of atmospheric air samples with excess of hygienic standards has revealed that the production facilities have recently introduced new technological processes and equipment that meet the requirements of the latest available technologies, as well as improving the quality of automotive fuel.

The increased levels of the revealed and potential risk factors established within the framework of the atmospheric air quality monitoring can form additional associated cases of the respiratory, immune, nervous, endocrine, musculoskeletal, reproductive, circulatory, blood and hematopoietic organs, eyes mucous, influence the processes of the organism development and other effects [11].

The total number of population diseases associated with environmental factors is gradually decreasing due to a gradual reduction in air pollution in settlements. In 2019 the number of additional diseases from all causes related to air pollution of residential areas in the Russian Federation probably was on average 600.0 cases per 100.000 population (it was 2.1 times less than in 2012: 1238.1 cases per 100.000 population, $p < 0.05$).

Respiratory diseases (ICD class 10: J00-J99) accounted for the major part of the structure of additional cases in the total population of the Russian Federation (69.4 %) [14], digestive diseases (K00-K93) occupied the second place (9.75 %), diseases of the circulatory system (I00-I99) occupied the third place (9.04 %), diseases of the blood and hematopoietic organs and certain disorders involving the immune mechanism (D50-D89) occupied the fourth place (4.34 %), other classes of diseases contributed less than 3 % to the structure of associated cases.

In 2019, the respiratory diseases of the entire population in 41 regions of the Russian Federation were associated with air pollution by nitrogen oxides, carbon monoxide, suspended solids, ammonia, dihydrosulfide, chlorine, hydroxybenzene and its derivatives, formaldehyde, nitrogen oxide, nitrogen dioxide, benz(a)pyrene, etc. Tyumen Region has the highest level of additional associated respiratory diseases (more than 12.100 deaths per 100.000 peoples) and Krasnodar Region has the lowest level (0.83 deaths per 100.000 people). The priority territories by the number of diseases in this class potentially associated with the aerogenic factor of the environment also include Tyumen, Amur, Belgorod, Irkutsk, Kirov regions, Altai Territory, the Republic of Kalmykia, the Vologda Region, the Republic of Khakassia and the Republic of Buryatia (from 1055.7 to 12120.8 additional cases per 100.000 people).

The hygienic analysis showed that in 2019 the rate of asthma and asthma status associated with air quality among children (0–14 years) was on average 3.63 additional cases per 100.000 children of the same age and was 2.4 times lower than in 2012. In 2019, 38 regions of the Russian Federation registered cases of asthma and asthma status potentially associated with air quality. This indicator exceeded the average Russian level in 12 subjects of the Russian Federation, with the highest levels in Irkutsk Region, Krasnoyarsk Territory, Republics of Buryatia, Bashkortostan, and Khakassia (12.11–58.06 additional cases per 100.000 children of the corresponding age).

According to the research results, in 2019 air pollution formed from 0.8 to 11.6 additional cases of asthma and asthma status per 100.000 adults of working age. In Russia as a whole (2019 – 0.45 ⁰/₀₀₀₀) the number of additional cases of asthma associated with air pollution in the adult working-age population decreased by 2.5 times as compared to 2012 (1.125 ⁰/₀₀₀₀).

In 2019, air pollution caused additional cases of chronic and unspecified bronchitis and emphysema among children in 39 regions of the Russian Federation, ranging from 0.14 to 85.11 cases per 100.000 children. Chelyabinsk, Belgorod, Amur regions, the Republic of Bashkortostan, and Saratov region have the highest levels (range from 57.9 to 85.1 words per 100.000 children). In Russia as a whole, the number of additional cases of children's morbidity due to this reason associated with air pollution decreased by 2.1 times as compared to 2012 (in 2019 – 10.7 cases, and in 2012 – 22.05 cases per 100.000 children).

The indicator of the morbidity of chronic and unspecified bronchitis associated with the air quality and emphysema of adult working-age population was registered in 31 regions of the Russian Federation at the level from 0.4 to 157.8 cases per 100.000 adults. On the whole Russia, the number of additional cases due to the above-mentioned reason associated with air pollution decreased by 57.0 % as compared to 2012 in dynamics (2019 – 13.4 ⁰/₀₀₀₀, in 2012 – 31.1 ⁰/₀₀₀₀).

The results of risk assessment in 12 priority cities showed that all cities had unacceptable risk levels. The

priority factors for the formation of carcinogenic, acute and chronic non-carcinogenic risks include suspended solids, formaldehyde, nitrogen oxide, nitrogen dioxide, ammonia, nickel oxide, gasoline, sulfuric acid, benzene, benzene(a)pyrene, acrylonitrile, sulfur dioxide.

The priority cities had unacceptable levels of acute and chronic non-carcinogenic risk for respiratory organs: acute risk levels ranged from 2.01 HI to 5.39 HI and chronic levels from 1.38 HI to 24.1 HI. The minimum level of acute non-carcinogenic risk for respiratory organs developed in Nizhny Tagil (up to 2.01 HI), the maximum – in Omsk (up to 5.39 HI), the minimum level of chronic risk was registered in Cherepovets (up to 1.36 HI), the maximum – in Nizhny Tagil (up to 24.1 HI).

In addition, there were unacceptable levels of chronic non-carcinogenic risk formed in relation to the immune system – from 3.48 HI (Norilsk) to 4.69 HI (Nizhny Tagil); central nervous system – from 2.65 HI (Norilsk) to 7.11 HI (Nizhny Tagil); visual organs – from 1.51 HI (Chelyabinsk) to 6.13 HI (Nizhny Tagil); cardiovascular system – from 1.31 HI (Nizhny Tagil) to 2.62 HI (Norilsk); blood systems – from 1.38 HI (Cherepovets) to 5.58 HI (Nizhny Tagil); of the reproductive system – from 2.16 HI (Norilsk) to 3.4 HI (Nizhny Tagil); liver and kidneys – 3.64 HI (Nizhny Tagil); developmental disorders – from 2.31 HI (Nizhny Tagil) to 3.04 HI (Krasnoyarsk).

There were unacceptable levels of carcinogenic risk for both adults and children in urban areas: Nizhny Tagil (2.92×10^{-3} and 2.72×10^{-3} respectively), Novokuznetsk (2.42×10^{-4} and 2.26×10^{-4} respectively), and Norilsk (2.39×10^{-4} and 2.23×10^{-4} respectively). The main factors forming carcinogenic risk in cities included benzene, acrylonitrile, carbon (soot), etc.

In 12 cities, the number of additional cases from all causes related to air pollution exceeded the national average (600.0 cases per 100.000 people).

According to the results of a comparative assessment in absolute terms, the largest number of cases associated with the quality of the air, diseases of the entire population in 2019 probably formed in Krasnoyarsk (51.200 cases), Chelyabinsk (49.300 cases), Magnitogorsk (39.000 cases). In relative cases, Magnitogorsk (9.432 persons per 100.000), Bratsk (6.977 persons per 100.000), Krasnoyarsk (4.673 persons per 100.000) and Chelyabinsk (4.104 persons per 100.000) occupied priority positions in the number of additional cases of the total population.

Respiratory diseases (from 14.8 to 96.8 %) significantly contributed to the structure of associated morbidity in these cities. The priority risk factors were nitrogen oxide, nitrogen dioxide, formaldehyde, benz(a)pyrene, hydroxybenzene and its derivatives, ammonia, dihydrosulfide, chlorine (from 30.4 to 90.2 %).

According to the research results in 2019, Bratsk formed over 15.900 additional associated cases (6 977 cases per 100.000 people). Respiratory diseases (93.9 %) and diseases of the musculoskeletal system (6.1 %) significantly contributed to the associated morbidity.

More than 51.200 additional associated cases were registered in Krasnoyarsk (4.673 per 100.000 people).

Respiratory diseases (96.4 %) and diseases of the musculoskeletal system (3.3 %) made their main contribution to the structure of associated morbidity.

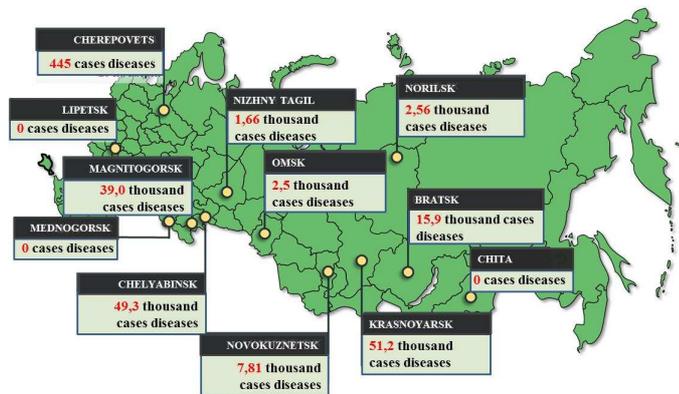


Figure 2 Number of associated cases of diseases potentially associated with air quality in priority cities (in abs. values)

In 2019 Magnitogorsk had more than 39.000 additional potentially associated cases of diseases (9.432 cases per 100.000 people). The main contributors were respiratory diseases (96.8 %), circulatory diseases (1.6 %), blood and hematopoietic diseases (1.0 %).

There were about 1.660 additional associated cases in Nizhny Tagil (467 cases per 100.000 people). Respiratory diseases (65.9 %), digestive diseases (32.2 %) and diseases of the nervous system (1.9 %) were the main contributors to the associated morbidity.

Novokuznetsk has registered more than 7.800 additional associated cases (1417.9 cases per 100.000 people). The main contribution to the structure of associated diseases was made by diseases of the circulatory system (38.1 %), blood and hematopoietic organs (22.3 %), respiratory diseases (14.8 %), nervous system diseases (13.4 %), diseases of the musculoskeletal system and connective tissue (11.4 %).

In 2019, Norilsk accounted for over 2.560 additional cases (1.411 cases per 100.000 people) of associated diseases. Respiratory diseases (41.7 %), diseases of the digestive organs (57.0 %) and diseases of the nervous system (1.2 %) made the main contribution to the structure of associated diseases.

Omsk has recorded about 2.500 additional cases of associated diseases (215 cases per 100.000 people). Respiratory diseases (83.2 %) and digestive diseases (15.9 %) contributed mainly to the associated morbidity.

Chelyabinsk has recorded 49.300 additional associated cases (4.104 cases per 100.000 people). Respiratory diseases (56.6 %), diseases of the digestive organs (24.9 %), diseases of the circulatory system (8.8 %), diseases of the blood and hematopoietic organs (5.2 %), diseases of the nervous system (4.5 %) made the main contribution due to associated diseases.

In 2019 Cherepovets accounted for over 440 additional cases of associated diseases (140.6 cases per 100.000

people). Digestive system diseases (94.9 %) and nervous system diseases (5.1 %) were the main contributors to the associated morbidity.

In Lipetsk and Mednogorsk registered levels of exposition according to the data of 2019 probably did not form additional cases of health disorders. This situation may result from the lack of summary dispersion calculations in these areas and, as a consequence, the failure to implement an optimal air quality monitoring program.

On the whole, the integrated system of air protection measures implemented in the Russian Federation over a number of years resulted in the improvement of air quality and reduction of additional associated morbidity of the population caused by its negative impact.

4. CONCLUSION

The results of the study showed the following:

1. Over the last twenty years (2000–2019) the hygienic indicators of air quality in populated areas in the Russian Federation have improved significantly: the level of non-standard samples has decreased by 10.5 times. Priority substances decreased by 3.9–12.9 times.

2. In dynamics the number of additional cases of diseases from all causes related to air pollution of residential areas is decreasing (in 2000–2019 – by 2.1 times), in 2019 in Russia as a whole this indicator was 600.0 cases per 100.000 population.

3. Respiratory diseases (69.4 %) accounted for the major share of additional cases in the total population of the Russian Federation, followed by diseases of the digestive organs (9.75 %), diseases of the circulatory system (9.04 %) and diseases of the blood and hematopoietic organs and certain disorders involving the immune mechanism (4.34 %).

4. The morbidity of the entire population with respiratory diseases is probably associated with atmospheric air pollution with nitrogen oxides, carbon monoxide, suspended solids, ammonia, dihydrosulfide, chlorine, hydroxybenzene and its derivatives, formaldehyde, nitrogen oxide, nitrogen dioxide, benz(a)pyrene, benzene, acrylonitrile, carbon (soot), and other substances.

5. The results of the assessment of non-cancerogenic risk to public health, expressed by hazard coefficients and indices, showed that on the territory of 12 priority cities the hazard indices for respiratory organs exceeded the allowable level (HI=1) and were within the range of 2.01 HI ((Nizhny Tagil) to 5,39 HI (Omsk) for acute exposure, and in the range of 1.36 HI (Cherepovets) to 24,1 HI (Nizhny Tagil) – for chronic exposure.

6. Unacceptable levels of chronic non-carcinogenic risk were also formed for the immune system – from 3.48 HI to 4.69 HI; central nervous system – 2.65 HI to 7.11 HI; organs of vision – from 1.51 HI to 6.13 HI; cardiovascular system – 1.31 HI to 2.61 HI; blood system – 1.38 HI to 5.58 HI; reproductive system – 2.16 HI to 3.4

HI; liver and kidney – 3.64 HI; developmental disorders – 2.31 HI to 3.04 HI.

7. The following cities have determined unacceptable levels of carcinogenic risk for both adult and child populations: Nizhny Tagil (up to 2.92×10^{-3} and 2.72×10^{-3} , respectively), Novokuznetsk (up to 2.42×10^{-4} and 2.26×10^{-4} , respectively), and Norilsk (up to 2.39×10^{-4} and 2.23×10^{-4} , respectively). The main factors forming carcinogenic risk in these cities include benzene, acrylonitrile and carbon.

8. Among the 12 polluted cities, the following cities registered the largest number of associated cases of the total population: Krasnoyarsk (more than 51.200 cases), Chelyabinsk (more than 49.300 cases), Magnitogorsk (more than 39.000 cases). cases), in relative terms – in Magnitogorsk (over 9.400 cases per 100.000 people), Bratsk (over 6.980 cases per 100.000 people), Krasnoyarsk (over 4.670 cases per 100.000 people), Chelyabinsk (over 4.100 cases per 100.000 people).

9. Respiratory diseases (up to 96.8 %) contributed the most to the structure of the associated morbidity. The priority risk factors were nitrogen oxide, nitrogen dioxide, formaldehyde, benz(a)pyrene, hydroxybenzene and its derivatives, ammonia, dihydrosulfide, chlorine (from 30.4 to 90.2 %).

10. The results of the research show that the integrated system of air protection measures implemented in the Russian Federation over a number of years has made it possible to improve air quality and reduce the additional associated morbidity of the population caused by the negative impact of polluted air.

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