The dynamic analysis of atmospheric air quality and the reasons for its change in the Russian Federation

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Abstract. The study concerns the problem of analyzing the quality of ambient air in the Russian Federation over the past twenty years and determining the causes that influence its change. It is shown that the air quality in urban and rural settlements improves, despite the absence of sustainable positive dynamics in reducing gross emissions of stationary and mobile sources. To explain this phenomenon, it has been suggested that as a result of the spatial redistribution of the location of the emissions sources, residential, recreational and other standardized zones, the sources of exposure to atmospheric air are removed from the places of population. The main substances that affect the atmospheric air quality in the Russian Federation are benzo(a)pyrene, ethylbenzene, carbon, suspended solids, hydrogen fluoride, mercury, hydroxybenzene, hydrogen sulfide, carbon monoxide and acrolein. The study showed that atmospheric pollution with benzo(a)pyrene decreased 3.14 times, with suspended solids 9.36 times, with carbon monoxide 9.28 times, and with hydroxybenzene 8.74 times. There was a reduction in exposure of carbon monoxide emissions (by 1.236 million tons, VOCs (by 580 thousand tons) and nitrogen oxides (by 297 thousand tons). The quality of ambient air and its change in the Russian Federation was influenced by a number of natural and anthropogenic factors such as adverse weather conditions for dispersion of impurities in the atmosphere, forest fires, industrial accidents and disasters, implementation of planning decisions on the territory of urban and rural settlements, allowing to place emission sources into the ambient air at the necessary distance from residential areas, and to implement the principle of distance protection and etc.

1. Introduction

Human existence depends on the air they breathe. Air quality has a huge impact on human health and well-being.

Under current Federal Law of May 4, 1999 No. 96 – FZ “About protection of atmospheric air, the quality of atmospheric air is understood as “a set of the physical, chemical and biological properties of atmospheric air reflecting degree of its compliance to hygienic standard rates of quality of atmospheric air and to ecological standard rates of quality of atmospheric air”. Chemical substances or mixtures of substances that enter it or form in it in concentrations that exceed quality standards pollute the atmospheric air.
Both natural (forest fires, dust storms, etc.) and anthropogenic sources contribute to air pollution. Human activities are the major sources of air pollution, for instance fuel combustion from motor vehicles, heat and electricity production, industrial and agricultural facilities, including livestock and poultry facilities, as well as waste storage facilities [5].

In this regard, the assessment of atmospheric air quality in populated areas, both urban and rural, is the basis for managerial decisions to reduce its pollution and ensure the constitutional rights of citizens of the country to a favorable and safe living environment. The results of instrumental studies are one of the most informative and reliable sources of information about the level of air pollution. Instrumental studies are performed by both state bodies within the framework of environmental [1] and socio-hygienic monitoring [2], scheduled and unscheduled inspections, and economic entities themselves as part of production control.

The results of instrumental studies make it possible to identify potentially dangerous impurities that pose a risk to human health, both during short-term and long-term exposure, and priority sources of pollution [3, 4].

Control actions to reduce pollution and improve air quality have enormous potential for improving health and help reduce the burden of noncommunicable diseases.

A dynamic assessment of atmospheric air quality is the basis for making managerial decisions and developing action plans to reduce atmospheric air pollution, minimize risk and harm to public health.

2. Problem statement and research methods

The purpose of the study was to carry out a hygienic analysis of atmospheric air quality in the Russian Federation over the past twenty years and to determine the causes that influence its change. The subject of the research was the results of atmospheric air samples studies of urban and rural settlements of the Russian Federation for 2000–2019, as well as data on the amount of pollutants emitted from stationary and mobile sources into the atmospheric air.

To achieve this goal, a hygienic analysis of data from departmental statistical form No. 18 “Information on the sanitary conditions of the subject of the Russian Federation” of the Federal Service for the Oversight of Consumer Protection and Welfare (Rospotrebnadzor) was conducted for 2000–2019. Data were analyzed on the total number of samples studied in urban and rural settlements, as well as on the number and proportion (%) of samples exceeding the maximum permissible concentrations (MPC) of pollutants. These data were analyzed throughout the country, in relation to urban and rural settlements of 85 constituent entities of the Russian Federation for 2000–2019. The study analyzed data on more than 40 chemicals polluting the air: nitrogen dioxide, nitrogen oxide, acrylates, aliphatic unsaturated hydrocarbons, aliphatic saturated hydrocarbons, amines (aliphatic and aromatic, dimethyl formaldehyde, etc.), ammonia, aromatic hydrocarbons, benzene, benzo(a)pyrene, suspended solids, suspended particles (PM2.5 and PM10), hydroxybenzene and its derivatives, hydrogen sulfide, cadmium, xylene, maleic anhydride, manganese, arsenic, pesticides, polychlorinated biphenyls, 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.

The data of the Federal Service for Supervision of Natural Resources (Rosprirodnadzor) on pollutants emitted from stationary and mobile sources in the atmospheric air of the Russian Federation were also analyzed for 2000–2018. Heavy metal dynamics (divanadium pentaoxide, cadmium oxide, manganese and its compounds, copper oxide, nickel, mercury, lead and its inorganic compounds, chromium, arsenic and its inorganic compounds) emitted from stationary sources, as well as total emissions of sulfur dioxide, nitrogen oxides, carbon monoxide, volatile organic compounds from stationary and mobile sources were studied.
3. Main results
In order to improve atmospheric air quality on the territory of the Russian Federation, Rospotrebnadzor and Rosprirodnadzor regularly monitor the level of pollution and the level of exposure to atmospheric air. The results of these observations make it possible to prepare and justify a list of measures aimed at reducing air pollution in both urban and rural settlements.

An analysis of the data of the federal statistical observation form No. 18 “Information on the sanitary conditions of the subject of the Russian Federation” showed that over the past twenty years (2000–2019), the air quality of the populated areas in the Russian Federation has significantly improved. The share of atmospheric air samples with excesses of maximum permissible concentrations (MPC) for the study period decreased by 10.5 times, including in cities by 10.7 times, in rural settlements - by 5.3 times.

At the same time, the analysis of data from Rosprirodnadzor for 2000–2018 showed that the total volume of pollutant emissions during the study period did not change significantly: from 31.228 to 35.835 million tons/year.

The share of stationary sources in the total emissions was also quite stable and ranged from 52.8 to 60.5%, and mobile - from 39.5 to 47.2%. The main stationary sources of emissions are enterprises of fuel and energy, petrochemical, oil refining, metallurgical and other complexes.

In 2018, the total volume of pollutant emissions amounted to 32.327 million tons, which is only 0.026 million tons higher than the 2000 figure. In 2018, 1.752 million tons pollutants emitted from stationary sources which is less than in 2000. Pollutant emissions from mobile sources increased over the period 2000–2018 by 1.778 million tons and amounted to 15.259 million tons, including from vehicles - 15.108 million tons, from railway transport - 151 thousand tons.

Thus, an analysis of the data of Rospotrebnadzor and Rosprirodnadzor showed that the change in gross emissions of pollutants had a slight effect on the dynamics of improving the quality of atmospheric air in populated areas.

A probable explanation of the obtained results may be that the sources of impact on the atmospheric air are removed from the places of residence due to the environmentally acceptable placement of housing and public utilities on the territory of urban and rural settlements, construction of bypass roads, gasification, landscaping and site finishing, planting green spaces with maximum gas filtering ability to reduce pollution from roads, planting hedges from shrubs, shelter along pedestrian paths and sidewalks to prevent the spread of soils on the road surface, etc.

A comparative analysis of the constituent entities of the Russian Federation on the specific gravity of atmospheric air samples exceeding hygienic standards showed that over the past ten years, the maximum values of this indicator were recorded in the Chukotka Autonomous Okrug (42.86% of the samples with excess, 2017), the Transbaikal Territory (26, 8% of samples, 2011), Magadan Oblast (18.86% of samples, 2011), Republic of Dagestan (13.29% of samples, 2011), Republic of Buryatia (13.15% of samples, 2011), Republic of Ingushetia (12.5% of samples, 2014) and the Republic of Khakassia (10.47% of samples, 2011).

In 2019, the list of priority subjects of the Russian Federation with the highest share of atmospheric air samples of urban and rural settlements that do not meet hygienic standards included 9 out of 12 entities located in the Siberian Federal District (Republic of Tyva, Republic of Buryatia, Irkutsk Oblast, Transbaikal Territory, Krasnoyarsk Kray, Kemerovo Oblast, Altai Krai, Novosibirsk Oblast, Tomsk Oblast), 2 of 9 subjects of the Far Eastern Federal District (Chukotka Autonomous Okrug, Sakhalin Oblast), 1 of 6 subjects of the Southern Federal District (Republic of Kalmykia), 1 of 18 subjects of the Central Federal District (Kursk Oblast), 1 of 14 subjects of the Volga Federal District (Saratov Oblast).

It is noteworthy that the territories with the highest level of atmospheric air pollution are located in the Asian part of Russia: in the Siberian and Far Eastern Federal Districts. In these areas, adverse weather conditions for dispersion of impurities in the atmosphere (surface inversions, air stagnation, high air temperature, low precipitation) are often observed which contribute to the accumulation of pollutants in the air.
A dynamic assessment of air quality in the priority subjects of the Russian Federation showed that for the period 2010–2019 the proportion of atmospheric air samples with excess of MPC decreased in the Transbaikal Territory (by 84.8%), Krasnoyarsk Krai (by 42.1%), Kemerovo Oblast (by 15.2%) and Altai Krai (by 26.2%). Despite these positive trends, a significant increase in the share of atmospheric air samples in excess of hygiene standards was observed in the Republic of Buryatia (+ 91.7%), Irkutsk Oblast (+ 123.4%), Sakhalin Oblast (+ 94%) and Novosibirsk Oblast (+107.4%).

An analysis of the data of the Rospotrebnadzor on the atmospheric air pollution of the Russian Federation with certain chemicals and compounds showed that in 2019 the list of priority pollutants included: benzo(a)pyrene, ethylbenzene, carbon (soot), suspended solids, hydrogen fluoride, mercury, hydroxybenzene, hydrogen sulfide, carbon oxide and acrolein.

For the period 2000–2019 a significant decrease in the specific gravity of atmospheric air samples was recorded with hygiene standards exceeding benzo(a)pyrene (3.14 times), suspended solids (9.36 times), carbon oxide (9.28 times) and hydroxybenzene (8.74 times).

According to the data of Rospririodnadzor during 2000–2018, gaseous and liquid substances prevailed in the total volume of pollutants emitted into the air of the Russian Federation (from 92.5 to 95.2%). Carbon monoxide (from 47.5 to 51.5%) made the largest contribution to air pollutant emissions. Emissions from stationary and mobile sources increased over the study period by 1.236 million tons and reached the level of 16.596 million tons. Emissions of volatile organic compounds (by 580 thousand tons) and nitrogen oxides (by 297 thousand tons) also increased. At the same time, the share of nitrogen oxides in emissions from stationary sources and vehicles for the period under review remained unchanged and ranged from 10.4% to 10.9%. Over the period 2000–2018, gross emissions of sulfur dioxide (by 1.818 million tons), solids (primarily carbon black), methane and ammonia decreased.

Assessment of the dynamics of heavy metal emissions showed that in general it has a positive trend. For the period 2010–2018 emissions of divanadium pentoxide, cadmium oxide, copper oxide, nickel, chromium mercury and arsenic reduced. An increase in emissions over the reporting period was noted for manganese and lead. In 2018, the emissions of manganese and its compounds amounted to 1,467.9 tons, of lead and its compounds - 169.5 tons, which is 45.4% and 107.8% respectively higher than in 2017 and 72.6% and 71.2% respectively higher than in 2010.

An analysis of the influence of factors likely to influence the change in atmospheric air quality showed that the following natural and anthropogenic factors can be attributed to the main reasons:

- adverse weather conditions for dispersion of impurities in the atmosphere;
- forest fires;
- technological accidents and disasters;
- burning solid and liquid fuels for energy and heat supply to the population (autonomous sources of heat supply) and production facilities (industrial and agricultural);
- the use of outdated technological processes and equipment that do not meet the requirements of the best available technologies;
- transfer of transport to "environmentally friendly" types of fuel;
- development of road infrastructure, construction of new and updating of bypass motorways;
- creation of a “green framework” in residential areas aimed at reducing the level of air pollution by creating conditions for self-cleaning of the atmosphere;
- implementation of planning decisions on the territory of urban and rural settlements, allowing to place sources of emissions into the atmospheric air at the necessary distance from residential areas, and to implement the principle of distance protection, etc.

4. Conclusions

The results of a dynamic analysis of atmospheric air quality in the Russian Federation showed that over the past twenty years (2000–2019), the air quality of populated areas has significantly improved. The share of atmospheric air samples with excesses of maximum permissible concentrations (MPC) for the
study period decreased by 10.5 times, including in cities by 10.7 times, in rural settlements - by 5.3 times. The most significant decrease in the specific gravity of atmospheric air samples that do not comply with hygienic standards was noted for benzo(a)pyrene (3.14 times), suspended solids (9.36 times), carbon oxide (9.28 times) and hydroxybenzene (8.74 times) and other pollutants.

The analysis showed that the priority subjects of the Russian Federation with the highest level of air pollution are most often located in the Asian part of Russia (in the Siberian and Far Eastern Federal Districts), where adverse weather conditions for dispersion of impurities in the atmosphere are typically observed which contributes to the accumulation of pollutants.

The total volume of pollutants emitted into the atmosphere from sources during the study period did not change significantly: from 31.228 to 35.835 million tons/year. At the same time, emissions of carbon monoxide (by 1.236 million tons), volatile organic compounds (by 580 thousand tons) and nitrogen oxides (by 297 thousand tons) increased slightly. Gross emissions of sulfur dioxide (by 1.818 million tons), solid substances (primarily carbon black), methane and ammonia decreased. The dynamics of heavy metal emissions also showed a decrease (by 17.9 thousand tons).

The main reasons affecting the change in atmospheric air quality in the Russian Federation include a number of both natural and anthropogenic factors.

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