Assessment of ambient air quality in areas influenced by fuel and energy enterprises to provide environmental safety of the population

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Abstract. The article provides the spatial-dynamic and structural hygienic assessment of influence exerted by fuel and energy enterprises on ambient air quality and potential public health risks in the Russian Federation. An average potential health risk level ($R_{av}$) equaled $5.44 \times 10^{-4}$ per one economic entity operating in the ‘Electrical power, gas and steam supply; air conditioning’ branch in the RF as a whole. In the RF regions, the highest potential health risk level per one economic entity was identified in the Siberian Federal District where it equaled $9.9 \times 10^{-4}$. According to the Register, the exposure level ($M_i$) established for economic entities operating in the ‘Electrical power, gas and steam supply; air conditioning’ branch and belonging to extremely high and high risk categories varies within the range of $0.0928 - 0.0093$ and $0.00921 - 0.00092$ million people accordingly; a potential health risk level identified for such economic entities equals $1.11 \times 10^{-3} - 0.17$ and $1.0 \times 10^{-4} - 9.8 \times 10^{-4}$ accordingly.

1 Introduction

Provision of energy safety of the Russian Federation and its regions, satisfaction of relevant demands within socioeconomic development of the country as regards sufficient volumes and quality of energy resources, as well as provision of workplaces and sufficient personnel and production competences are the top priorities fixed in the State Energy Policy of the Russian Federation [1].

The energy system of the Russian Federation consists of the Unified Energy System (UES) that includes seven combined energy systems (CES): the Central, Volga, Urals, North West, South, Siberia, and East [2].

A considerable part (almost 40 %) of all the electrical power in Russia is produced by thermal power plants (TPP) [3-4]. Nuclear power plants, hydroelectric power plants, power plants fueled by natural gas and renewable energy sources generate more than a half of electrical energy in the country [5]. The demand for electrical energy grows every year and the branch develops constantly searching for new energy sources and applicable technologies; an important task is to improve operating thermal power plants, raise their reliability and environmental safety [6].

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According to Russian and foreign studies, thermal power plants can produce negative effects on ambient air, water objects and soils, and, consequently, on public health. Besides, operations of such energy objects involve emissions of greenhouse gases [7, 8].

The scale of effects produced by thermal power plants on the environment largely depends on fuels used in them. Major energy sources include organic fuels (coal and shale oils, oils, and natural gas), nuclear and thermonuclear fusion, renewable energy sources (water, wind, sunlight, thermal waters, wood, turf, etc.) [9-13].

Thermal power plants fueled by coal and turf account for a considerable share (17.9%) of all the fuel and energy enterprises in Russia. They mostly belong to the CES Siberia (the Siberian Federal District) and East (the Far East Federal District). In the Siberian Federal District, thermal power plants fueled by coal, turf and boiler oil account for 90.7%; this share is higher than 53% in the Far East Federal District.

According to statistical reports and relevant research works, emissions from thermal power plants contain the most widely spread pollutants typical for stationary emission sources; they are carbon oxide, carbon dioxide, sulfur dioxide, hydrocarbons, benz(a)pyrene, particulate matter, and ammonia. Apart from the aforementioned pollutants, thermal power plants emit greenhouse gases (methane and ozone), fluorides, volatile organic compounds (VOC), carbon (soot), inorganic dusts, wood and boiler oil soot, mineral oil and others. Some Russian and foreign authors publish articles that address levels of some metal oxides in emissions from fuel and energy enterprises including oxides of vanadium, aluminum, iron, calcium, magnesium, etc. [14-17].

Over the last 5 years, several National and Regional projects have been actively implemented in the Russian Federation including such Federal projects as Clean Air, Clean Country, and Russia’s Energy Strategy. In addition, various environmental protection measures have been implemented as well; among other things, they are aimed at improving ambient air quality including areas influences by economic entities dealing with electrical energy, gas and steam supply [8, 17].

As expected, implementation of all the existing national projects will facilitate transition to an environmentally friendly and resource-saving power engineering, which will improve the environmental and sanitary-epidemiological situation in large industrial regions in the country and mitigate potential health risks for people living in areas influenced by fuel and energy enterprises.

2 Materials and methods

In accordance with the Russian Classification of Economic Activities, fuel and energy enterprises operate in the sphere entitled ‘Electrical power, gas and steam supply; air conditioning’ (code 35).

We analyzed emissions of pollutants into ambient air from stationary sources, fuel and energy enterprises included, using data collected by the Federal Environmental, Industrial and Nuclear Supervision Service of Russia (Rosprirodnadzor) in 2017-2021.

The quantity of ambient air samples with levels of pollutants not conforming to the standards was analyzed as per data taken from state reports issued by Rospotrebnadzor in 2017-2021.

We estimated the number of economic entities operating in the ‘Electrical power, gas and steam supply; air conditioning’ branch using data form the Federal Register of Juridical Persons and Private Entrepreneurs Subject to Sanitary-Epidemiological Surveillance (hereinafter called the Register) as of January 2022.

Potential public health risks ($R^p$) caused by fuel and energy enterprises were identified as likelihood that the sanitary-epidemiological legislation would be violated ($p^l$) multiplied by severity of health outcomes (relative health harm) due to such violation ($u^r$) and a level
of population exposure created by an economic entity \( (M_i^r) \). Its average level \((R_{\text{av}}^i)\) was identified as a ratio of all the summated risks to the quantity of economic entities in accordance with the Methodical Guidelines MR 5.1.0116-17 ‘Risk-based model for control and surveillance activities in the sphere of providing sanitary-epidemiologic well-being. Ranking economic entities, types of activities, and objects under surveillance as per potential risks of damage to health for organizing scheduled control and surveillance activities’.

### 3 Results

According to the data taken from Rosprirodnadzor state reports, the total emissions of pollutants into ambient air reduced by 9.8 thousand tons (30.5 %) in the Russian Federation between 2017 and 2021 and amounted to 22.3 thousand tons in 2021.

Over the last 5 years, gross pollutant emissions into ambient air from stationary sources (including enterprises dealing with electrical power, gas and steam supply and air conditioning) reduced by 1.5 % on the national level between 2017 and 2021 and equaled 17.2 thousand tons in 2021. Emissions from enterprises dealing with electrical power, gas and steam supply and air conditioning accounted for 17.8 % in the total emissions from all the stationary sources in the Russian Federation in 2021. The share of pollutant emissions from stationary sources in the Siberian Federal District accounted for 32 % in the total emissions form stationary sources in the country.

We compared emissions as per different Federal Districts in the RF; the analysis revealed that the greatest amounts of emissions from stationary sources, thermal power plants included, were registered in 2021 in the Siberian (5631.7 thousand tons), Ural (3655.5 thousand tons), and Volga (2508.8 thousand tons) Federal Districts (Figure 1).

![Graph](https://example.com/graph.png)

**Fig. 1.** Pollutant emissions from stationary sources, including enterprises operating in ‘Electrical power, gas and steam supply; air conditioning’ as per the RF Federal Districts in 2021, thousand tons.

According to the data taken from the State Reports on Environmental Protection issued in 2017-2021, thermal power plants mostly emit carbon oxide, carbon dioxide, nitrogen oxides, sulfur dioxide, volatile organic compounds (VOC), hydrocarbons, metal oxides (aluminum, iron, calcium, magnesium), benz(a)pyrene, vanadium oxides, soot, and greenhouse gases (methane and ozone).

According to the data taken from the State Reports on Environmental Protection, ambient air quality did not conform to the existing hygienic standards in the Siberian and Far Eastern Federal Districts in 2017-2021. Maximum permissible levels (MPL) were
violated for such pollutants as carbon oxide (levels in ambient air are up to 9.1 times higher than MPL); nitrogen oxide (3.4 times higher); nitrogen dioxide (2.9 times); sulfur dioxide (4.0 times); benz(a)pyrene (2.15 times); particulate matter (7.6 times); ammonia (9.7 times); xylene (36.5 times); toluene (14.8 times); phenol (24.3 times); formaldehyde (39.0 times); and some other pollutants.

Relying on statistical data, we established that the greatest number of samples with pollutant levels deviating from the standards was registered in 2021 in the Siberia, Ural, and Far Eastern Federal Districts (1.4–2.0%). In 2021, the structure of pollutant emissions from stationary sources, including thermal power plants, contained several harmful chemicals in levels not conforming to the hygienic standards. The greatest shares of non-conforming samples were registered for carbon oxide (0.12-1.9%), benz(a)pyrene (3.8-21.1%), hydrocarbons (3.9-4.9%), particulate matter (1.12-2.5%), toluene (2.3-9.8%), xylene (4.3-19.2%), formaldehyde (0.7-3.1%), and ammonia (0.4-1.4%).

According to the Register (as of January 2022), the greatest number of thermal power plants were located in the Central (20.9% of all the economic entities), Siberia (18.0%), Volga (17.8%) and Far Eastern (14.3%) Federal Districts.

An average potential health risk amounted to $5.44 \times 10^{-4}$ per one economic entity ($R^l_{av}$) operating in the ‘Electrical power, gas and steam supply; air conditioning’ branch on the national level; the same indicator $R^l_{av}$ amounted to only $4.62 \times 10^{-4}$ for industrial enterprises. The share of economic entities operating in this sphere and assigned into extremely high and high risk categories (categories 1 and 2 accordingly) as pewr potential health harm amounted to 21.7 %; signifacnt potential risks (category 3), 34.6 %; medium risk (category 4), 30.4 %; moderate risk (category 5), 11.5 %; low risk (category 6), 1.8 % (Figure 2).

Fig. 2. Economic entities operating in ‘Electrical power, gas and steam supply; air conditioning’ as per potential risk categories in the Russian Federation.

Average weighted frequency of violated mandatory sanitary-epidemiological requirements per one inspection (a control and surveillance activity in relation to a certain economic entity) ($p(l)$) and potential harm to public health due to these violations amounted to 5.59 and 0.0194 accordingly for all the economic entities operating in the ‘Electrical power, gas and steam supply; air conditioning’ branch (according to the modeling results in accordance with the Methodical Guidelines MR 5.1.0116-17.). Differences that determine the ultimate value of potential health risks ($R^l$) created by activities of fuel and energy enterprises for each particular economic entity come from differences in the indicator that describes the number of people exposed to the $i$-th industrial facility ($M_1$, exposure level, million people).
According to the Register, the exposure level ($M_i$) established for economic entities operating in the ‘Electrical power, gas and steam supply; air conditioning’ branch and belonging to extremely high and high risk categories varies within the range of 0.0928 – 0.0093 and 0.00921 – 0.00092 million people accordingly; a potential health risk level ($R_i^l$) identified for such economic entities equals $1.03 \times 10^{-2} - 1.01 \times 10^{-3}$ and $9.9 \times 10^{-4} - 1.0 \times 10^{-3}$ accordingly.

The greatest share of economic entities operating in this sphere and belonging to extremely high and high risk categories (categories 1 and 2 accordingly) is registered in the Siberia, Volga, Central, Ural, and Far Eastern Federal Districts and equals 78.5%.

Comparative analysis as per the RF Federal Districts revealed that the highest average potential health risk per one economic entity ($R_i^{av}$) for electrical power, gas and steam supply and air conditioning was equal to $9.88 \times 10^{-4}$ and was registered in the Siberia Federal District (Figure 3).

At present, fuel and energy enterprises are considered an important economy branch; they create significant potential public health risks in areas influenced by their negative effects. Given that, it is relevant to investigate causes and conditions for health disorder associated with ambient air quality in areas influenced by thermal power plants. We are going to conduct further research in the sphere.

### 4 Discussion

It has been reported in some studies [18-21] that thermal power plants are significant sources of ambient air pollution in cities. Further use of coal as a major energy source in some regions in the country and its growing share in the country fuel balance can have negative influence on the environment and incidence among exposed population.

At present, active modernization is taking place at thermal power plants; the existing equipment is being updated and new environmentally friendly and clean units and boilers are being put into operation. Implementation of Federal projects and plans for complex air protection activities motivates thermal power plants to implement the best available technologies and automated systems for continuous instrumental industrial control. This will make it possible to achieve practical results as regards reduction of ambient air pollution created by thermal power plants.
We can name several promising trends aimed at reducing negative influence exerted by thermal power plants on the environmental quality, ambient air in particular. They include switching to environmentally friendly fuels such as liquefied natural gas, biofuels and use of natural gas for unconventional deposits; use of energy-saving equipment (intellectual networks within the country Unified Electrical Energy System; intellectual mini- and micro-networks based on distributed generation), etc. [22].

5 Conclusion

The Project ‘Effective and Environmentally Friendly Thermal Power Production’ [22] involves implementation of several ecological and environmental protection activities as regards thermal power plants by 2030:

- Developing solutions aimed at switching to advanced thermal power units fueled by natural gas with high service properties.
- Using highly efficient thermal power units on solid fuels that are safe for the environment (inter-cycle gasification of a solid fuel).
- Using advanced thermal power units with a low-temperature cycle.
- Implementing new types of energy-generating units based on piston technologies.
- Developing new technologies for direct transformation of chemical energy into electrical one with high efficiency and long-term operation time.
- Developing new technologies for environmentally friendly combustion of organic fuels and combustive wastes.
- Developing highly effective technologies for splitting and purifying gas mixtures and liquids for advanced energy and technological plants etc.

As expected, these activities will bring about implementation of the new generation of thermal power plants powered by organic fuels. They will be created specifically to meet all the legal requirements as regards environmental protection and to prevent climate change; in future, all this may have positive effects on public health.

Data reported in multiple studies indicate that elevated levels of chemical pollutants in ambient air created by thermal power plants may produce negative effects on the respiratory organs, the immune, nervous genitourinary, musculoskeletal, reproductive, and circulatory systems, etc. [23-24].

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