Energy power facilities as a source of air and environmental pollution

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Abstract. The paper presents a spatial-dynamic and structural hygienic assessment of the impact of thermal power facilities on the atmospheric air quality. It was established that the average potential risk of harm to health per economic entity operating in the field of thermal power engineering, \(R_{av}\), amounted to \(1.17 \times 10^{-3}\). The proportion of entities carrying out this activity and belonging to extremely high and high (1 and 2, respectively) categories of potential risk of harm was 21.7%. The degree of impact (\(M\)) for economic entities implementing activities in the field of thermal power engineering and referring to extremely high and high categories in terms of potential risk of harm is in the range of 0.0069-0.93 and 0.00068-0.152 million people, respectively, and the level of potential risk of harm to health (\(R_l\)) for these categories of economic entities – \(1.0 \times 10^{-3}-0.101\) and \(1.0 \times 10^{-3}-1.0 \times 10^{-4}\) respectively. The largest number of economic entities of categories 1 and 2 – extremely high and high potential risk, respectively, operates in the Volga, Central, Siberian and North-Western federal districts of the Russian Federation.

1. Introduction

Currently, electricity is one of the leading sectors of the national economy. The global energy industry is undergoing major changes, due to which this industry will radically change in the long-term perspective. The development of various types of energy on a global scale led to an unprecedented increase in living standards [1]. Most of world energy is generated by the thermal power plants (TPP), the second place belongs to hydroelectric power stations (HPS), on the third place – nuclear power. Among all thermal power facilities, thermal power plants and boiler plants are considered the most unfavourable in terms of the impact on the environment [2-3].

In Russia, thermal power industry occupies one of the leading places in the country’s economy. The power supply system of the Russian Federation consists of the unified energy system, which includes seven integrated power systems: Center, Middle Volga, Ural, Northwest, South, Siberia and East: land-wise isolated power supply systems (Chukotka Autonomous Okrug, Kamchatka Krai, Sakhalin and Magadan regions, Norilsko-Taimyrsky and Nikolaevsky power districts, power supply systems of a northern part of the Sakha (Yakutia) Republic) [4].

The main sources of energy include organic fuel (coal and combustible shale, oil, natural gas), nuclear and thermonuclear energy, renewable energy resources (water, wind, sun, thermal water, wood, peat, etc.) [5-8].

The quality of atmospheric air is an essential component for ensuring an enabling environment for
human activity. Human activity requires not only the presence of air, but also its sufficient purity. Industrial thermal power engineering enterprises, including boiler plants, negatively affect the air pollution [9]. In 2018, 566 thermal power plants, 74.8 thousand boiler plants functioned in Russia. The largest volumes of total heat output from thermal power plants are recorded in the Central, Volga and Siberian federal districts. They account for 21, 27 and 19% of the total heat output in the Russian Federation, respectively [10].

Despite this, in general over 2000-2019 the Russian Federation faced a decrease in the share of the total number of emissions by 30%, including from thermal power plants – by 3.1% (from 20.5 to 17.4%). Hygienic indicators of atmospheric air quality in populated areas in the Russian Federation have improved significantly over the past 20 years. During this period, the share of atmospheric air samples with exceeded maximum permissible concentrations (MPC) decreased 10.5 times (from 6.07 to 0.58%), including in urban areas – by 10.7 times (from 6.28 to 0.59%), in rural areas – by 5.3 times (from 2.81 to 0.53%) [11-12].

As a result of production activities of electric power industry enterprises (burning of organic solid and liquid fuels) such substances as hydrocarbons, volatile organic compounds, hydrogen sulfide, nitrogen oxides, carbon monoxide, sulfurous anhydride and others enter the environment with atmospheric emissions [13-15].

Over the past 5 years, environmental measures, federal and regional projects, including the federal projects Clean Air, Clean Country, Energy Strategy of Russia, have been actively implemented, within the framework of which measures are being taken to improve the quality of atmospheric air, including at business entities engaged in electric energy, gas and steam supply [16].

In line with current trends that take into account the fuel resource endowment, technological improvements, economic and environmental impacts of rising emissions of pollutants into the atmosphere determine the relevance of this study.

2. Materials and methods
The purpose is to carry out a spatial-dynamic and structural hygienic assessment of the impact of thermal power facilities on the atmospheric air quality and the development of potential risks of harm to the health of the Russian population.

In accordance with the Russian National Classifier of Economic Activities, thermal power facilities in the Russian Federation carry out activities in the field of “Electric energy, gas and steam supply; air conditioning” (code 35).

To achieve this purpose, the data of Rosprirodnadzor on pollutant emissions for 2000-2019 were analyzed, reflecting the impact of stationary sources, including enterprises supplying electric energy, gas and steam, on the atmospheric air of the constituent entities of the Russian Federation.

To estimate the number of entities carrying out activities on “Electric energy, gas and steam supply; air conditioning”, the authors used data of the Federal Register of Legal Entities and Individual Entrepreneurs (hereinafter – the Register) for September 2020.

The potential risk of harm to the health of the population (Rl) caused by the economic activity of production facilities was defined as the product of the probability of violation of sanitary and epidemiological legislation (p(l)), the severity of health consequences (relative harm to health) in the breach of the legislation (u(l)) and the scale of impact on the population by the business entity (Mi) (production facility) in accordance with MR 5.1.0116-17 [17].

Hygienic analysis of indicators of atmospheric air pollution and the number of inspections was carried out according to the data of the departmental statistical form No. 18 “Information on the sanitary condition of a constituent entity of the Russian Federation” of Rospotrebnadzor over 2000-2019.

3. Results
According to Rosprirodnadzor, the total pollutant emissions into the atmospheric air for the period from 2000 to 2019 decreased by almost 30% (9,585.8 thousand tons) and in 2019 amounted to 22,734
thousand tons. Over the past 20 years, a decrease in emissions of pollutants into the atmosphere from stationary sources has been recorded (including from electric, gas and steam utilities). Compared to 2000, total emissions from stationary sources decreased by 8.1% and in 2019 amounted to 17,295 thousand tons (76.1% of total emissions).

Total emissions of harmful substances into the atmosphere as a whole in the industry – “Electric energy, gas and steam supply; air conditioning” decreased by 3.1% compared to 2000 and in 2019 amounted to 3004.2 thousand tons (17.37% of all emissions from stationary sources) (Fig. 1).

According to the Register of Economic Entities (legal entities/private entrepreneurs) subject to sanitary and epidemiological control/supervision (as of September 2020), the total number of entities carrying out activities referring to the “Electric energy, gas and steam supply; air conditioning” amounted to more than 6 thousand. An indicator of the average potential risk of harm to health per business entity ($R_{av}$) in the implementation of activities under “Electric energy, gas and steam supply; air conditioning” was $1.17 \times 10^{-3}$, while $R_{av}$ in the group “Activities of industrial enterprises” it amounted to $8.11 \times 10^{-3}$.

In terms of federal districts in 2019, the largest number of enterprises engaged in “Electric energy, gas and steam supply; air conditioning” was recorded in the Central (1,292 business entities), Siberian (1,114 entities) and Volga (1,100 entities) federal districts.

At the same time, the proportion of entities implementing this type of activity and referring to extremely high and high (1 and 2, respectively) category by potential risk of harm was 21.7%, to the category of considerable potential risk (category 3) – 34.6%, average potential risk (category 4) – 30.4%, moderate potential risk (category 5) – 11.5%, low potential risk (category 6) – 1.8% (Fig. 2).
Figure 2. Structure of economic entities (legal entities/private entrepreneurs) implementing activities under “Electric energy, gas and steam supply; air conditioning”, according to the categories of risk of harm to health in the Russian Federation.

The values of indicators of the weighted average frequency of violations of mandatory sanitary and epidemiological requirements per one inspection (control and supervisory measures in relation to a business entity) \( p(l) \) and indicators of potential harm to human health due to their possible non-compliance \( u(l) \) in the implementation of activities under “Electric energy, gas and steam supply; air conditioning” for all business entities implementing this type of activity are equal (according to simulation results) to 5.59 and 0.0194, respectively (MR 5.1.0116-17) [17]. The differences determining the final value of the potential risk of harm to health \( R_l \) by the activity referring to power supply by an individual business entity are due to the difference in the indicator characterizing the population that is under the influence of the \( i \) production facility \( M_i \), degree of impact, million people.

According to the Register, the degree of impact \( M_i \) for business entities implementing activities under “Electric energy, gas and steam supply; air conditioning” and referring to extremely high and high categories in terms of potential risk of harm is in the range of 0.0069-0.93 and 0.00068-0.152 million people, respectively, and the level of potential risk of harm to health \( R_l \) for these categories of economic entities is \( 1.0 \times 10^{-3}-1.0 \times 10^{-4} \) and \( 1.0 \times 10^{-5}-1.0 \times 10^{-4} \) respectively.

The analysis of distribution of economic entities (legal entities/private entrepreneurs) implementing activities under “Electric energy, gas and steam supply; air conditioning” according to the categories of potential risk of harm to health in the context of the regions of the Russian Federation (Fig. 3) indicates that the maximum number of economic entities of categories 1 and 2 – extremely high and high potential risk, respectively, are located in the Volga Federal District (Republic of Mari El, Mordovia, Bashkortostan, Ulyanovsk, Nizhny Novgorod, Penza, Orenburg regions, Chuvash, Udmurt republics), Central (Moscow, Tula, Kostroma, Vladimir, Tambov, Smolensk, Moscow, Ryazan, Lipetsk, Tver regions), Siberian (Republic of Tuva, Omsk, Kemerovo, Tomsk, Irkutsk, Tyumen, Novosibirsk regions, Krasnoyarsk Territory) and the North-West (Novgorod, Murmansk, Leningrad, Arkhangelsk regions, Nenets Autonomous Okrug, Komi Republic) federal districts.
Figure 3. Distribution of economic entities (legal entities/private entrepreneurs) implementing activities in the field of “Electric energy, gas and steam supply; air conditioning”, according to the categories of potential risk of harm to health in the regions of the Russian Federation

The dimensional analysis shows that the potential risks of causing harm to health formed by the economic activity of constituent entities of various categories in the field of “Electric energy, gas and steam supply; air conditioning” are characteristic of most regions of the Russian Federation (Fig. 4).
According to scientific research, the main types of emissions from thermal power plants include carbon monoxide, carbon dioxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, hydrocarbons, metal oxides (aluminum, iron, calcium, magnesium), benzpyrene, vanadium oxides, carbon black, greenhouse gases (methane, ozone).

In the past 20 years, emissions of the most common air pollutants from stationary sources have decreased. For example, emissions of solid substances decreased by 6.48% (1,360.9 thousand tons), sulphur dioxide – by 7.47% (1730.4 thousand tons), carbon oxides – by 1.4% (163.3 thousand tons), vanadium oxide – by 9.33% (1770.8 thousand tons) compared to 2000. An unfavorable trend in increasing emissions from stationary sources was recorded with regard to the following substances: nitrogen oxides – the level of emissions since 2000 increased by 1.38% (100.6 thousand tons), hydrocarbons – by 8.59% (1267.9 thousand tons), volatile organic compounds – by 2.83% (421.1 thousand tons).

Currently, thermal power facilities belong to leading industries and form significant potential risks of causing harm to public health in the zone of their negative impact. In this regard, further study of the causes and conditions of health disorders associated with atmospheric air quality in the zones of influence of thermal power facilities is an urgent task and a vector of further research for the authors of this paper.

4. Conclusion
The total emissions of pollutants into the atmospheric air for the period from 2000 to 2019 decreased by almost 30% (9,585.8 thousand tons) and in 2019 amounted to 22,734 thousand tons. Total emissions of harmful substances into the atmosphere as a whole in the industry – “Electric energy, gas and steam supply; air conditioning” decreased by 3.1% compared to 2000 and in 2019 amounted to 3,004.2 thousand tons (17.37% of all emissions from stationary sources).
The indicator of the average potential risk of harm to health per one business entity ($R_{av}$) in the implementation of activities under “Electric energy, gas and steam supply; air conditioning” $R_{av}$ was $1.17 \times 10^{-3}$.

In 2019, the largest number of enterprises carrying out activities under “Electric energy, gas and steam supply; air conditioning” was recorded in the Central (1,292 business entities), Siberian (1,114 entities) and Volga (1,100 entities) federal districts.

The share of entities implementing activities under “Electric energy, gas and steam supply; air conditioning” and referring to extremely high and high (1 and 2, respectively) categories of potential risk of harm was 21.7%.

The maximum number of business entities of categories 1 and 2 – extremely high and high potential risk, respectively, are located in Siberian (258), Volga (227), Central (210) and North-West (142) federal districts.

The degree of impact ($M$) for business entities implementing activities on "Provision of electric energy, gas and steam; air conditioning," extremely high and high categories in terms of potential risk of harm is in the range of 0.0069–0.93 and 0.00068–0.152 million people, respectively, and the level of potential risk of harm to health ($R$) for these categories of economic entities is $1.0 \times 10^{-3}$–$0.10$ and $1.0 \times 10^{-3}$–$1.0 \times 10^{-4}$, respectively.

During the period from 2000 to 2019, emissions of the most common and priority pollutants into the atmosphere from stationary sources, including for thermal power facilities, decreased: emissions of solids decreased by 6.48% (1,360.9 thousand tons), sulphur dioxide – by 7.47% (1730.4 thousand tons), carbon oxides – by 1.4% (163.3 thousand tons), vanadium oxide – by 9.33% (1770.8 thousand tons) compared to 2000. An unfavorable trend in increasing emissions from stationary sources was recorded with regard to the following substances: nitrogen oxides – the level of emissions since 2000 increased by 1.38% (100.6 thousand tons), hydrocarbons – by 8.59% (1267.9 thousand tons), volatile organic compounds – by 2.83% (421.1 thousand tons).

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