UDC 613; 614
DOI: 10.21668/health.risk/2021.4.07.eng

Read online

Research article

FUEL AND ENERGY ENTERPRISES AS OBJECTS OF RISK-ORIENTED SANITARY-EPIDEMIOLOGIC SURVEILLANCE

A.M. Andrishunas[1], S.V. Kleyn[1,2]

[1]Federal Scientific Center for Medical and Preventive Health Risk Management Technologies, 82 Monastyrskaya Str., Perm, 614045, Russian Federation
[2]Perm State Medical University named after Academician E.A. Wagner, 26 Petropavlovskaya Str., Perm, 614000, Russian Federation

The present research aims to provide analytical support for the risk-oriented model of sanitary-epidemiologic control over fuel and energy enterprises. The research task were to reveal the most common violations of sanitary-epidemiologic requirements by fuel and energy enterprises; to determine priority environmental indicators that should be included into a program of laboratory support for control and surveillance activities; to estimate actual impacts exerted by fuel and energy enterprises.

We established that in 2020 there were totally more than 6 thousand economic entities that performed their activity in the sphere of "Electric energy, gas and steam supply; air conditioning". Since fuel and energy enterprises tend to be located close to residential areas, violations in the sphere of ambient air protection (Clause 20) involve negative influence on a considerable number of people. In 2020 the greatest number of revealed violation regarding requirements to ambient air quality was registered for heat and power engineering enterprises in the Far East Federal District (FEFD), Siberian FD (SFD), Central FD (CFD), and Ural FD (UFD) and varied from 10.6 to 42.9 %. Average potential health risk (R^{I}_{av}) per one economic entity amounted to $5.44 \cdot 10^{-4}$ for heat and power engineering. A share of economic entities dealing with this economic activity and assigned into extremely high and high (the 1st and 2nd accordingly) risk categories as per potential health risk amounts to 21.7 %. A scale of exposure (M^{I}_{i}) for economic entities operating in heat and power engineering can reach 930 thousand people. The greatest share of economic entities belonging to the 1st and 2nd risk categories as per potential health risk is registered in the SFD, Volga FD, CFD, UFD, and FEFD and amounts to 78.5 %.

The greatest average potential health risk per one economic entity (R^{I}_{av}) in the sphere of "Electric energy, gas and steam supply; air conditioning" was registered in the Siberian Federal District and amounted to $9.88 \cdot 10^{-4}$. The greatest numbers of economic entities operating in the sphere of "Electric energy, gas and steam supply; air conditioning" that belonged to the 1st and 2nd risk categories as per potential health risk are located in the Krasnoyarsk region (37.9 %), Kemerovo region (32.6 %), Tomsk and Omsk regions (29.7 % each).

Key words: *heat and power engineering enterprises, emissions, ambient air quality, potential health risk, a scale of exposure, violation of legislation.*

Energy security of the country and its regions, providing necessary support to socio-economic development, preservation of existing workplaces in the brunch and creation of new ones together with providing sufficient personnel and industrial competences are top priorities outlined in the State Energy Strategy of the Russian Federation [1]. The most significant trends in the development of the Russian Energy System are being implemented in each of its seven components or so called combined energy systems (CES): The Central, Middle Volga, Urals, Northwestern, South, Siberia, and Eastern CES [2]. Energy consumption in Russia is predicted to grow by 35–45 % by 2030 (against 2005) and its growth rates are likely to be approximately by two times higher than on average in the world [3].

The Russian fuel and energy complex is a necessary basis and integral part of the country economy, its industrial and communal sectors; at the same time the complex is a source of envi-

Alena M. Andrishunas – Junior researcher (e-mail: ama@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-0072-5787).

Svetlana V. Kleyn – Doctor of Medical Sciences, Head of the Department for Systemic Procedures of Sanitary-Hygienic Analysis and Monitoring (e-mail: kleyn@fcrisk.ru; tel.: +7 (342) 237-18-04; ORCID: https://orcid.org/0000-0002-2534-5713).

ronmental hazards and pollution [4, 5]. Energy-producing enterprises exert negative influence on ambient air, water objects and soils and, consequently, on population health [6–9]. The gravest and most apparent environmental issues are associated with coal-powered thermal power stations and stations powered by other fossil fuels (peat or shale oil) and/or heavy oil [10].

At present coal accounts for approximately 15 % in the energy balance of the Russian Federation. Bearing in mind that next generations are very likely to face oil and gas deficiency, coal, together with developing non-organic energy production, will remain a basic organic fuel used for different purposes, including production of electricity [11–14][1].

Without doubt, coal processing and utilization technologies are going to be developed further; a predicted technology in the sphere is coal being converted into synthetic liquid or gaseous fuel [3, 12]. However, at present coal-powered heat and power engineering enterprises still exert significant adverse impacts on the environment and ambient air on urbanized territories [13, 14]. These issues are aggravated on some territories due to orographic, climatic, and layout-related peculiarities of their location. Thus, potential of emission dispersion is rather low in the Eastern Siberia and it creates elevated concentrations of pollutants in ground air [9, 15]. And we should remember that coal is a prevailing energy carrier in this part of the country. In the Siberian Federal District (SFD) a share of thermal power stations that are primarily powered by coal, heavy oil and peat amounts to 90.7 %; it exceeds 53 % in the far Eastern Federal District (FEFD) (Figure 1).

Thermal power stations located on lowlands or in close proximity to residential areas create significant health risks. Besides, we should remember that, apart from thermal power stations, there are large numbers of private boiler stations and autonomous heat sources that operate on “problem” territories in Russia; in 2018 more than 74.8 thousand such objects were registered in the country. Private boiler stations tend to have low chimneys and, consequently, they create greater ambient air pollution in the bottom layers in the atmosphere from which people breathe air [14]. The greatest number of autonomous heat sources powered by fossil fuels is also located in the Siberian and Far Eastern Federal Districts (Krasnoyarsk region, Transbaikalia, Kemerovo region, Irkutsk region, and Novosibirsk region). Such objects are usually located within residential areas or in the closest proximity to them and it may result in negative effects on ambient air quality and, consequently, on exposed population’s health [16].

Such pollutants as carbon oxide, carbon dioxide, nitrogen oxides, sulfur dioxide, hydrocarbons, benz(a)pyrene, particular matter and ammonia are basic components in emissions from heat and power engineering enterprises [8, 9, 16–19][2]. Apart from them, heat and power engineering objects emit greenhouses gases (methane and ozone), fluorides, volatile organic compounds (VOC), carbon (soot), non-organic, abrasive and wood dust, heavy oil ashes, mineral petroleum oil and some other admixtures into the atmosphere. Some Russian and foreign authors provide data in their works on metal oxides occurring in emissions from fuel and energy enterprises including oxides of vanadium, aluminum, iron, calcium, magnesium, etc. [16, 20]. We should note that instrumental measurements in zones influenced by fuel and energy objects often allow detecting such dust admixtures in environmental objects and ambient air that are not usually included into inventory environmental lists. As it has been shown by Revich [4] and Petrov [5], solid particles in emissions from fuel and energy enterprises can contain compounds of manganese, chromium, copper, nickel, arsenic, lead, cadmium, and other toxic metals.

[1] Energeticheskaya strategiya Rossiiskoi Federatsii na period do 2035 goda (utv. rasporyazheniem Pravitel'stva Rossiiskoi Federatsii ot 9 iyunya 2020 g. № 1523-r) [The Energy Strategy of the Russian Federation for the period up to 2035 (approved by the RF Government Order dated June 9, 2020 No. 1523-r)]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/565068231 (August 20, 2021) (in Russian).

[2] O sostoyanii i ob okhrane okruzhayushchei sredy Rossiiskoi Federatsii v 2019 godu: Gosudarstvennyi doklad [On the ecological situation and environmental protection in the Russian Federation in 2019: The State report]. Moscow, The RF Ministry of Natural Resources and the Environment, M.V. Lomonosov’s Moscow State University, 2020, 1,000 p. (in Russian).

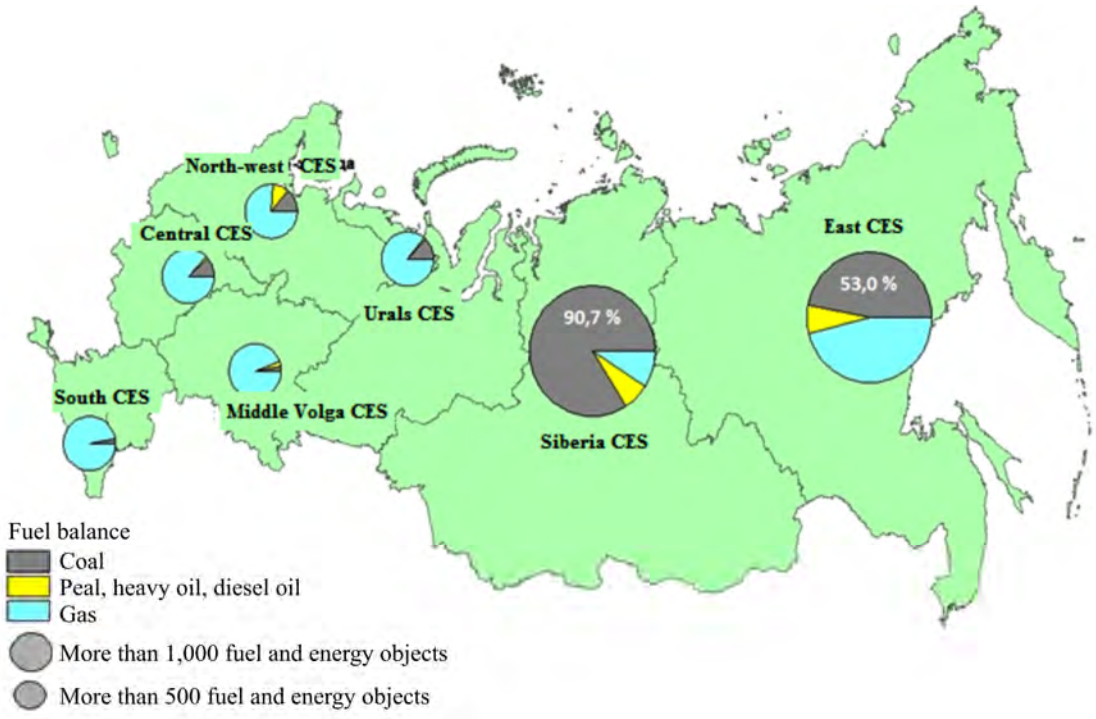

Figure 1. Fuel balance of the RF Combined Energy System, %
(A size of a pie chart corresponds to a number of fuel and energy objects powered by different fuels)

Over the last 10 years ambient air pollution has been characterized as "very high" and "high" in large industrial centers in the Siberian and Far Eastern Federal Districts with air pollution index varying from 9.3 to 22[2]; a significant contribution to these pollution levels and poor quality of the environment is made by fuel and energy enterprises.

According to data taken from the state reports on the ecological situation in the country[2] ambient air quality in SFD and FEFD doesn't correspond to hygienic standards. A lot of pollutants are registered in concentrations exceeding maximum permissible ones; first of all, we should mention carbon oxide (its concentration is by 9.1 times higher than MPC), nitrogen oxide (3.4 times), 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) etc.

Results of environmental and social-hygienic monitoring indicate that in 2020 the greatest number of ambient air samples that contained pollutants in quantities deviating from hygienic standards was registered in the Siberian, Ural, and Far Eastern Federal Districts (1.4–2.0 %)[2]. The greatest number of deviating ambient air samples in 2020 were registered as per 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 %) and we can conclude that these pollutants prevailed in emissions into ambient air from stationary sources, heat and power engineering enterprises included.

Elevated concentrations of chemicals in ambient air that typically occur in emissions from heat and power engineering enterprises can induce negative effects in the respiratory organs, immune, nervous, genitourinary, musculoskeletal and reproductive system, circulatory system etc; they can also make for development of various malignant neoplasms [4, 18, 21–23]. Up to 50 % cases of exacerbated chronic non-specific respiratory diseases that occur in industrial cities in Siberia are likely due to ambient air being polluted with emissions from industrial objects, heat and power engineering enterprises included [22, 24].

All the aforementioned calls for targeted risk-oriented control performed by sanitary-epidemiologic surveillance authorities; their primary task is to ensure than economic entities comply with the obligatory hygienic requirements to environmental protection and providing sanitary-epidemiologic welfare of the country population.

Our research aim was to provide analytical support for the risk-oriented model of sanitary-epidemiologic control over activities performed by fuel and energy enterprises complying with the obligatory requirements fixed in the sanitary legislation. The research tasks were to detect the most common violations of sanitary-epidemiologic requirements by fuel and energy enterprises; to determine priority environmental indicators that should be included into a program of laboratory support for control and surveillance activities; to estimate actual impact exerted by fuel and energy enterprises.

Materials and methods. According to the All-Russian classifier of types of economic activities, heat and power engineering enterprises operate in the sphere "Electric energy, gas and steam supply; air conditioning" (Code 35).

We took data from the Federal Register of juridical persons and private entrepreneurs that were subject to epidemiologic surveillance (hereinafter called the Register) as of December 2020 to estimate a number of economic entities who operated in the sphere "Electric energy, gas and steam supply; air conditioning".

Potential health risk (R^l) associated with economic activities performed by fuel and energy enterprises was determined as a probability that the sanitary-epidemiologic legislation would be violated (p^l) multiplied by gravity of outcomes for health (relative health harm) caused by violation of the legislation (u^l) and a scale of exposure caused by an economic entity (M^l_i); average risk rate (R^l_{av}) was calculated as a sum of all risks divided by a number of economic entities according to the Provisions on the federal state sanitary-epidemiologic control (surveillance) approved by the RF Government Order issued on June 30, 2021 No. 1100[3] and the Methodical Guidelines MR 5.1.0116–17[4].

Frequency of detected violations committed by economic entities that operated in the sphere "Electric energy, gas and steam supply; air conditioning" was estimated as per data taken from Rospotrebnadzor's departmental statistical report, The Federal statistical observation form No. 1-control "Data on accomplishing state control (surveillance) and municipal control" issued in 2014–2020.

Results and discussion. According to data taken from the Register of economic entities (juridical persons / private entrepreneurs or JP / PE for short) that were subject to sanitary-epidemiologic control / surveillance (as of December 2020), the overall number of economic entities operating in the sphere "Electric energy, gas and steam supply; air conditioning" amounted to more than 6 thousand. As for their distribution in the Federal Districts, in 2019 the greatest number of enterprises that provided population and industries with electricity, gas, and steam, were located in the Central FD (1,292 economic entities), Siberian FD (1,114 economic entities), Volga FD (1,100 economic entities) and Far Eastern FD (883 economic entities).

[3] O federal'nom gosudarstvennom sanitarno-epidemiologicheskom kontrole (nadzore): Postanovlenie pravitel'stva RF № 1100 ot 30 iyunya 2021 goda [On the federal state sanitary-epidemiologic control (surveillance): The RF Government Order No. 1100 dated June 30, 2021]. *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_389344/ (August 22, 2021) (in Russian).

[4] MR 5.1.0116-17. 5.1. Organizatsiya Gossanepidsluzhby Rossii. Risk-orientirovannaya model' kontrol'no-nadzornoi deyatel'nosti v sfere obespecheniya sanitarno-epidemiologicheskogo blagopoluchiya. Klassifikatsiya khozyaistvuyushchikh sub"ektov, vidov deyatel'nosti i ob"ektov nadzora po potentsial'nomu risku prichineniya vreda zdorov'yu cheloveka dlya organizatsii planovykh kontrol'no-nadzornykh meropriyatii: metodicheskie rekomendatsii (utv. Rukovoditelem Federal'noi sluzhby po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka, Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii A.Yu. Popovoi 11.08.2017) [The Methodical guidelines MR 5.1.0116-17. 5.1. Organization of the State sanitary-epidemiologic service in Russia. The risk-oriented model of control and surveillance activities in the sphere of providing sanitary-epidemiologic welfare. Classification of economic entities, types of activity and objects under surveillance as per potential human health risks for organization of scheduled control and surveillance activities: methodical guidelines (approved by the Head of the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, the RF Chief Sanitary Inspector A.Yu. Popova on August 11, 2017)]. Moscow, the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2017, 30 p.

Table 1

Frequency of violations of obligatory requirements fixed in the sanitary legislation by fuel and energy enterprises (a number of detected priority violations per 1 inspection)*

Clauses in the 52-FZ		2018	2019	2020	Growth rate, %
No.	Essence of a clause (requirements)				
Cl. 13	Requirements to products	0.095	0.031	0.015	–84.21
Cl. 17	To organization of catering	0.012	0.019	0.002	–83.33
Cl. 18	To water objects	0.105	0.054	0.032	–69.52
Cl. 19	To drinking water	0.586	0.539	0.727	**+24.06**
Cl. 20	To ambient air	0.387	0.395	0.415	**+7.24**
Cl. 21	To soils, industrial grounds	0.044	0.031	0.051	**+15.91**
Cl. 22	To waste disposal	0.348	0.351	0.134	–61.49
Cl. 23	To living premises	0.047	0.054	0.044	–6.38
Cl. 24	To maintenance of building and constructions	1.254	1.307	0.729	–41.87
Cl. 25	To working conditions	1.154	0.921	0.798	–30.85
Cl. 27	To sources of physical factors	0.381	0.271	0.129	–66.14

N o t e : * The table provides data on Clauses in the Federal Law 52-FZ that are violated the most frequently (> 0.05).

Table 2

A share of violations of requirements to ambient air fixed in the sanitary legislation (Clause 20 in the 52-FZ) by economic entities operating in the sphere "Electric energy, gas and steam supply; air conditioning" as per Federal Districts in the RF, 2014–2020, %

Federal District	2014	2015	2016	2017	2018	2019	2020	Growth rate, %
Central	8.9	15.1	13.8	4.4	8.5	4.8	20.0	+123.5
Northwestern	16.3	6.6	14.7	3.7	5.0	2.2	2.9	–85.6
Southern	0.5	3.9	9.2	8.1	2.5	3.2	1.8	+235.3
North-Caucasian	1.1	1.3	1.2	0.4	0.4	0.0	1.8	+67.6
Volga	7.9	11.5	4.0	2.2	3.6	15.0	5.9	–25.5
Ural	20.5	28.2	23.6	71.7	62.3	49.0	14.7	–28.4
Siberian	38.4	25.2	29.8	6.5	9.6	15.6	10.6	–72.4
Far Eastern	6.3	8.2	3.7	3.1	8.2	10.2	42.9	+579.9

Our analysis of data taken from the departmental statistical report Form No. 1-control "Data on accomplishing state control (surveillance) and municipal control" issued in 2014–2020 revealed that enterprises most frequently violated obligatory sanitary-epidemiologic requirements to working conditions, to maintenance of buildings, constructions, and premises, to quality of drinking water and water sources, and to ambient air (Table 1).

And if violations regarding safe working conditions or quality of drinking water at an object under surveillance mostly influence only workers employed at this object, then violations regarding ambient air protection (Clause 20) exert their influence on a significant number of people living in urban and rural settlements where fuel and energy enterprises are located. It was revealed that, according to the Register, in the Russian Federation a scale of exposure created by economic entities operating in fuel and energy sphere could reach up to 930 thousand people. In large cities where electricity and heat are usually supplied to population and industries by several generating enterprises, negative exposure due to emissions can cover the whole population.

In 2020 the greatest share of detected violations of obligatory requirements to ambient air protection (Clause 20) was established for fuel and energy enterprises located in Far Eastern FD, Central FD, Ural FD, and Siberian FD and varied from 10.6 to 42.9 % (Table 2).

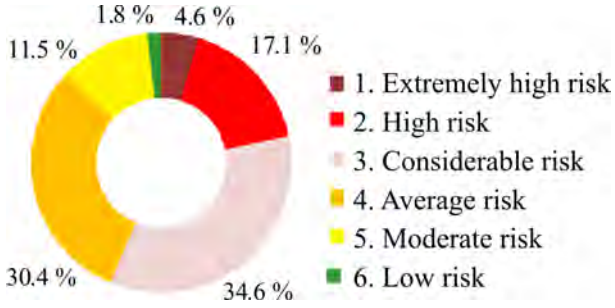

Figure 2. The structure of economic entities (JP / PE) operating in the sphere "Electric energy, gas and steam supply; air conditioning" as per potential health risk categories in the Russian Federation

Average potential health risk per one economic entity (R^{I}_{av}) operating in the sphere "Electric energy, gas and steam supply; air conditioning" amounted to $5.44 \cdot 10^{-4}$ in the RF but the indicator was higher in the primary group, "Activities performed by industrial enterprises", and mounted to $4.62 \cdot 10^{-4}$.

A share of economic entities that operated in the sphere and belonged to the extremely high risk and high hazard categories (hazard categories 1 and 2 accoridngly) as per potential health risk amounted to 21.7 %; 34.6 % economic entities belonged to the hazard category 3 (considerable potential health risk); 30.4 %, average risk (hazard category 4); 11.5 %, moderate risk (hazard category 5); and only 1.8 %, low risk (hazard category 6) (Figure 2).

The greatest share of economic entities operating in the sphere and belonging to the extremely high potential health risk and high potential health risk categories (hazard categories 1 and 2 accordingly) is registered in the Siberian, Volga, Central, Ural and Far Eastern FDs and amounts to 78.5 % (Table 3).

Comparative analysis performed as per the Federal Districts in the RF revealed the greatest average potential health risk per one economic entity (R^{I}_{av}) operating in the sphere "Electric energy, gas and steam supply; air conditioning" in the Siberian Federal District where this indicator amounted to $9.88 \cdot 10^{-4}$ (Figure 3).

Table 3

Distribution of economic entities (JP / PE) operating in the sphere "Electric energy, gas and steam supply; air conditioning" belonging to extremely high and high risk categories as per the Federal Districts in the RF, %

Risk category / Federal District	FEas	Vol	NWes	NCau	Sib	Ur	Cen	Sou	RF
A number of economic entities dealing with fuel and energy production in the hazard category 1 and 2	169	227	142	64	258	190	210	82	1,342
A share of economic entities belonging to the hazard categories 1 and 2, %	12.6	16.9	10.6	4.8	19.2	14.2	15.6	6.1	100

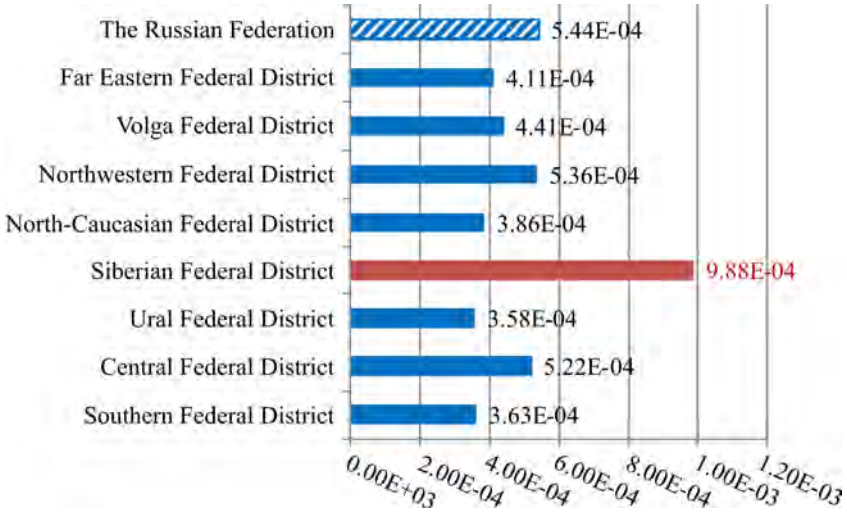

Figure 3. Average potential health risk per one economic entity (R^{I}_{av}) in the sphere "Electric energy, gas and steam supply; air conditioning" taken as per the Federal Districts in the RF

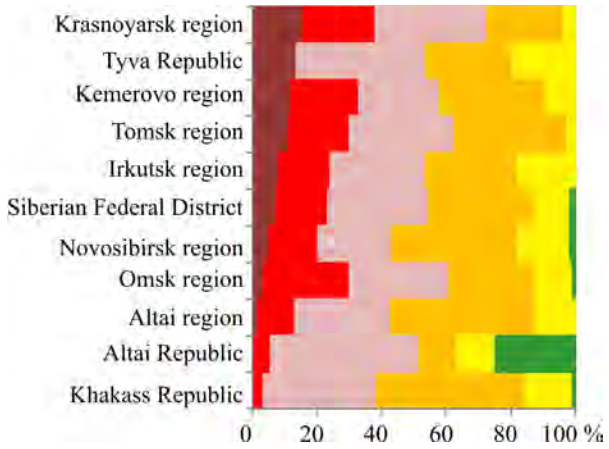

Figure 4. Distribution of economic entities (JP / PE) operating in the sphere "Electric energy, gas and steam supply; air conditioning" as per potential health risk categories as per regions located within the Siberian Federal District

The highest numbers of economic entities operating in the sphere "Electric energy, gas and steam supply; air conditioning" and belonging to the extremely high and high health risk categories were detected in Krasnoyarsk region (37.9 %), Kemerovo region (32.6 %), Tomsk and Omsk regions (29.7 % each) within the boundaries of the Siberian Federal District (Figure 4).

We performed more profound analysis of the situation in developed industrial centers in the Siberian and Far Eastern Federal Districts that were included into "Clean air" Federal project (Krasnoyarsk, Norilsk, Bratsk and Chita). The analysis revealed that in Krasnoyarsk and Norilsk (Krasnoyarsk region) potential health risk (R^I) caused by heat and power engineering enterprises amounted to $1.12 \cdot 10^{-4}$–$3.57 \cdot 10^{-3}$ for extremely high and high risk categories and exposure scale (M^I_i) amounted to 0.00103–0.0329 million people; in Bratsk (Irkutsk region) potential health risk (R^I) amounted to $1.09 \cdot 10^{-4}$–$7.92 \cdot 10^{-3}$ for economic entities operating in the sphere and exposure scale (M^I_i) was 0.001–0.073 million people; potential health risk (R^I) and exposure scale (M^I_i) amounted to $1.28 \cdot 10^{-4}$–$1.66 \cdot 10^{-3}$ and 0.00118–0.0153 million people accordingly in Chita (Transbaikalia).

Violations of hygienic standards are registered in these cities at posts for monitoring over ambient air quality located in zones influenced by fuel and energy enterprises; chemicals that are detected in concentrations exceeding MPC include particulate matter (up to 34.8 single maximum MPC, 1.4 average daily MPC), sulfur dioxide (up to 34.8 MPC_{sm}, 1.9 $MPC_{av.d}$), carbon oxide (up to 5.8 MPC_{sm}), nitrogen oxide (up to 2.9 MPC_{sm}, 1.3 $MPC_{av.d}$), and nitrogen dioxide (up to 1.5 MPC_{sm}, up to 2.1 $MPC_{av.d}$). A contribution made by fuel and energy enterprises to the total emissions from all sources varies from 75 to 90 %.

When requirements to ambient air quality and its protection are violated by fuel and energy enterprises, it can cause secondary pollution of soils, snow cover and surface water thus leading to health disorders and making the environment less comfortable for people. Bearing this in mind, we should stress that laboratory control and monitoring over ambient air quality in zones influenced by such objects are of primary importance.

In such cases results obtained through social-hygienic monitoring and/or targeted examinations can give grounds for interdepartmental inspections, reviewing inventory lists of emissions for such objects, establishing new standards for permissible emissions and / or projects of sanitary protection zones around such objects.

Therefore, the risk-oriented model for surveillance over compliance with obligatory requirements fixed in the sanitary legislation at fuel and energy enterprises should involve the following:

– priority control over compliance with the legislative requirements to protection of ambient air as well as other environmental objects including surface waters and soils on adjoining territories and natural water basins (Clauses 19, 20 and 21 In the Federal Law No. 52-FZ);

– a number of exposed population stated by an economic entity itself when a hazard category is determined should be controlled and verified by surveillance activities. This verification will allow avoiding underestimation of exposure scales for a specific object under surveillance. Fuel and energy enterprises located in the far eastern, Siberian and Ural

Federal Districts should be paid special attention when numbers of exposed population are determined for them;

– control and surveillance activities are to be provided with obligatory laboratory support regarding quantitative determination of components in emissions that pollute ambient air at boundaries between sanitary protection zones and the closest residential areas.

It seems advisable to provide scientific substantiation for risk indicators that are applied to determine whether obligatory requirements to ambient air protection are violated by heat and power enterprises. And a type of a fossil fuel a specific object is powered by is a key component in the procedure. Another vital task is to determine exact component and disperse structure of dusts emitted by a specific energy producing object since it allows the most precise determination of actual environmental pollution on adjoining territories and potential health risks for exposed population.

Funding. The research was not granted any sponsor support.

Conflict of interests. The authors declare there is no any conflict of interests.

References

1. Doklad o realizatsii Energeticheskoi strategii Rossii na period do 2030 goda po itogam 2018 [The report on implementing the Energy strategy of Russian for a period up to 2030: results achieved in 2018]. *Ministry of energy of Russian Federation*. Available at: https://minenergo.gov.ru/node/15357/ (16.08.2021) (in Russian).

2. Otchet o funktsionirovanii EES Rossii v 2019 godu [The report on functioning of the Russian Unified Energy System in 2019]. *Sistemnyi operator Edinoi energeticheskoi sistemy*, 2020, 36 p. Available at: https://www.so-ups.ru/fileadmin/files/company/reports/disclosure/2020/ups_rep2019.pdf (19.08.2021) (in Russian).

3. Makarov A.A., Veselov F.V., Makarova A.S., Novikova T.V., Pankrushina T.G. Strategic prospects of the electric power industry of Russia. *Thermal Engineering*, 2017, vol. 64, no. 11, pp. 817–828. DOI: 10.1134/S0040601517110064

4. Revich B.A. Assessment of the effect produced by the fuel and energy complex on the environment and health. *Studies on Russian Economic Development*, 2010, vol. 21, no. 4, pp. 403–410.

5. Petrov S.B., Petrov B.A. Assessment of health risk of particulate matter components of atmospheric emissions of multifuel power plants. *Ekologiya cheloveka*, 2019, no. 6, pp. 4–10. DOI: 10.33396/1728-0869-2019-6-4-10 (in Russian).

6. Karabekova A.A. Development of thermal energy: analysis, problems, prospects. *Izvestiya Sankt-Peterburgskogo gosudarstvennogo ekonomicheskogo universiteta*, 2017, no. 3 (105), pp. 123–127 (in Russian).

7. Netsvetaev A.G. Right protection of atmosphere air from pollution according to the legislation of the Russian Federation. *Pravovaya bezopasnost' lichnosti, gosudarstva i obshchestva: sbornik statei XIX Mezhdunarodnoi nauchnoi konferentsii*, 2019, pp. 108–116 (in Russian).

8. Peer R.A., Garrison J.B., Timms C.P., Sanders K.T. Spatially and Temporally Resolved Analysis of Environmental Trade-Offs in Electricity Generation. *Environ. Sci. Technol*., 2016, vol. 50, no. 8, pp. 4537–4545. DOI: 10.1021/acs.est.5b05419

9. Petrov A.S. Samarkina A.N. Issledovanie vliyaniya ob"ektov teploenergetiki na okruzhayushchuyu sredu [Examining influence exerted by heat-power engineering objects on the environment]. *Novaya nauka: Teoreticheskii i prakticheskii vzglyad*, 2016, no. 6–2 (87), pp. 152–154 (in Russian).

10. Kotler V.R. Environmental issues at the coal PP. *Okhrana truda i tekhnika bezopasnosti na promyshlennykh predpriyatiyakh*, 2016, no. 8, pp. 21–28 (in Russian).

11. Rynok elektroenergetiki Rossii i osnovnye igroki otrasli: analiticheskiy otchet [Electrical energy market in Russia and major players in the branch: analytical report]. *Analytic Research Group (ARG)*, 2018, 487 p. (in Russian).

12. Katin V.D., Maslov G.F., Dolgov R.V. Novye nailuchshie tekhnologii szhiganiya topliva v pechnykh i kotel'nykh ustanovkakh: monografiya [The latest best available technologies for burning fuel in furnaces and boiler plants: a monograph]. Moscow, OOO "Izdatel'stvo "Sputnik+", 2019, 175 p. (in Russian).

13. Tikhomirova T.I., Khomutov S.A. Vliyanie vrednykh vybrosov TETs na atmosferu [Influence exerted on the atmosphere by hazardous emission form thermal power stations]. *Bezopasnost', zashchita i okhrana okruzhayushchei prirodnoi sredy: fundamental'nye i prikladnye issledovaniya: sbornik trudov Vserossiiskoi nauchnoi konferentsii*, 2019, pp. 282–286 (in Russian).

14. Murtazina M.Sh., Panchenko M.A. Otsenka negativnogo vozdeistviya na ekologicheskoe sostoyanie okruzhayushchei sredy vybrosov zagryaznyayushchikh veshchestv v atmosferu ot predpriyatii teploenergetiki [Assessing negative influence on the ecological situation exerted by pollutants emitted into the atmosphere from heat-power engineering enterprises]. *Ekologiya i bezopasnost' v tekhnosfere: sovremennye problemy i puti resheniya: sbornik trudov Vserossiiskoi nauchno-prakticheskoi konferentsii molodykh uchenykh, aspirantov i studentov. V 2 tomakh*, 2015, pp. 263–266 (in Russian).

15. Rossiya uvelichit dolyu vozobnovlyaemykh istochnikov energii v 10 raz [Russia is going to raise a share of renewable energy sources by 10 times]. *TASS: Russian News Agency*, 2021. Available at: https://tass.ru/ekonomika/11787295 (30.08.2021) (in Russian).

16. Bakhtierova N.B., Suleimenova B.M. Vliyanie vybrosov predpriyatii teploenergetiki na okruzhayushchuyu sredu i zdorov'e naseleniya [Impacts exerted by emission form heat-power engineering enterprises on the environment and population health]. *Teoriya i praktika sovremennoi nauki*, 2016, no. 4 (10), pp. 110–113 (in Russian).

17. Zarubezhnaya elektroenergetika [Power industry abroad]. *Association NP "Market Council"*. Available at: http://www.eurasiancommission.org/ru/ (20.07.2021) (in Russian).

18. Golikov R.A., Kislitsyna V.V., Surzhikov D.V., Oleshchenko A.M., Mukasheva M.A. Assessment of the impact of air pollution by heat power plant emissions on the health of the population of Novokuznetsk. *Meditsina truda i promyshlennaya ekologiya*, 2019, vol. 59, no. 6, pp. 348–352. DOI: 10.31089/1026-9428-2019-59-6-348-352 (in Russian).

19. Kumar B., Kumar Verma V., Kumar S., Shekhar Sharma C. Polycyclic aromatic hydrocarbons in residential soils from an Indian city near power plants area and assessment of health risk for human population. *Polycyclic Aromatic Compounds*, 2014, vol. 34, no. 3, pp. 191–213. DOI: 10.1080/10406638.2014.883414

20. Issakhov A., Alimbek A., Issakhov A. A numerical study for the assessment of air pollutant dispersion with chemical reactions from a thermal power plant. *Engineering Applications of Computational Fluid Mechanics*, 2020, vol. 14, no. 1, pp. 1035–1061. DOI: 10.1080/19942060.2020.1800515

21. Penney S., Bell J., Balbus J. Estimating the Health Impacts of Coal-Fired Power Plants Receiving International Financing. *Environmental Defense Fund*, 2009. Available at: https://www.greenpeace.org/static/planet4-thailand-stateless/2019/03/e2c6b78f-e2c6b78f-9553_coal-plants-health-impacts.pdf (20.08.2021).

22. Karpin V.A. Current medico-ecological aspects of internal medicines in urbanic north. *Terapevticheskii arkhiv*, 2003, vol. 75, no. 1, pp. 31–34 (in Russian).

23. Selyunina S.V., Petrov B.A., Tsapok P.I. Zabolevaemost' naseleniya, prozhivayushchego v zonakh vliyaniya atmosfernykh vybrosov gorodskikh predpriyatii teploenergetiki [Population morbidity in zones influenced by missions from heat-power engineering enterprises]. *Vyatskii meditsinskii vestnik*, 2005, no. 2, pp. 64–67 (in Russian).

24. Bykova A.A., Fandeev N.P., Mishanov A.A. Otsenka riska zdorov'yu naseleniya pri energeticheskom zagryaznenii okruzhayushchei sredy [Health risk assessment under exposure to energetic environmental pollution]. *Vestnik mezhdunarodnoi akademii sistemnykh issledovanii. Informatika, ekologiya, ekonomika*, 2008, vol. 11, no. 1, pp. 95–97 (in Russian).

Andrishunas A.M., Kleyn S.V. Fuel and energy enterprises as objects of risk-oriented sanitary-epidemiologic surveillance. Health Risk Analysis, 2021, no. 4, pp. 65–73. DOI: 10.21668/health.risk/2021.4.07.eng

Received: 15.09.2021
Accepted: 09.12.2021
Published: 30.12.2021