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Moscow as an example of a methodological approach to a comprehensive assessment of the environmental safety of heat supply

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Abstract
The letter of the Ministry of Energy of the Russian Federation No. MU-4343/09, dated 15 April 2020, defines recommendations for the content of heat supply systems for cities in accordance with Decree of the Government of the Russian Federation No. 154, dated 22 February 2012. It is necessary to assess the environmental safety on urban heat supply. The authors propose a methodological approach to the development of the 'Environmental safety of heat supply' part, taking into account the regulatory framework of pollutant emissions that defined by regulatory legal acts in Russia. The article highlights the issues of creating a database of pollution sources, conducting an inventory of emissions, using automated algorithms to calculate the dispersion of pollutants, and creating a geo-information layer of pollutants for the electronic model of a heat supply system.
Keywords: ecology, heat supply scheme, atmospheric air protection, automation, dispersion of pollutants.

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以莫斯科为例综合评估供热环境安全的方法论

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简介
2020年4月15日俄罗斯能源部第MU-4343/09号"关于批准居民点和城市区域供热计划"的信函，根据2012年2月22日俄罗斯联邦政府第154号"关于供热计划的要求、制定和批准程序"的决议，确定了居民点供热计划内容的建议。作者特别指出，有必要对居民区供热的环境安全进行评估。作者提出了制定"供热环境安全"部分的方法论，包括考虑俄罗斯联邦环境安全和环境保护领域的规范性法案所规定的污染物排放规范性法律条例。 文章重点介绍了建立污染源数据库、编制污染物排放清单、使用自动算法计算扩散量以及在供热计划电子模型中形成污染物扩散地理信息层等问题。
关键词: 生态、供热计划、空气保护、自动化、污染物扩散。

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Introduction

The quality of atmospheric air plays a key role in ensuring environmental safety and public health and is regulated in the Russian Federation by regulatory legal acts that establish the basic requirements for environmental protection, control of emissions of pollutants (hereinafter referred to as PP) and ensuring the sanitary and epidemiological well-being of the population. The Constitution of the Russian Federation (hereinafter referred to as the Constitution) defines the rights of citizens to a favourable environment and reliable information about its condition, as well as the obligation to preserve nature and take good care of natural resources. The relevant provisions of the Constitution are reflected in the regulations governing not only the sphere of environmental protection, but also practically all sectors of the Russian Federation, including heat supply. Table 1 shows the regulatory legal framework for ensuring the quality of atmospheric air as part of federal laws in the sphere of environmental protection and energy, reflecting the articles of the Constitution.

In accordance with Part 1 of Article 3 of the Federal Law of the Russian Federation dated 27.07.2010 N 190-FZ 'On Heat Supply', one of the principles of the organisation of relations in the sphere of heat supply is to ensure the environmental safety of heat supply. According to Article 10 of the Decree of the Government of the Russian Federation dated 22.02.2012 N 154 'On Requirements to Heat Supply Schemes, the Procedure of Their Development and Approval'[1] (hereinafter – Decree 154), the heat supply scheme of settlements, municipal districts, city districts, cities of federal importance is subject to annual updating[2]. In accordance with Articles 2 and 23 of the Decree of the Government of the Russian Federation No. 154, when developing and updating heat supply systems for populated areas with a population of 100,000 people, one of the mandatory components of the heat supply system is the 'Electronic model of the heat supply system of a settlement, a municipal district, a city of federal importance'.

According to the Letter of the Ministry of Energy of the Russian Federation dated 15.04.2020 No. MU-4343/09 'On

Table 1
Regulatory framework for ensuring air quality: Federal laws in connection with Articles 42 and 58 of the Constitution of the Russian Federation

Federal law	Articles of the Constitution in the field of atmospheric air protection	
	Art. 42: Everyone has the right to a favourable environment and reliable information about its condition	Art. 58: Everyone is obliged to preserve nature and the environment and to treat natural resources with care
Federal Law No. 7-FZ of 10.01.2002 'On Environmental Protection'.	Establishes requirements for the provision of environmental information (Art. 4.3) Establishes the procedure for the creation of a federal state information system on the state of the environment (Art. 4.4) and a unified system of state environmental monitoring (Art. 63.1)	Defines the objects of environmental protection subject to state control (Art. 4, 69) Defines the standards in the field of environmental protection (Art. 19-31)
Federal Law No. 96-FZ of 04.05.1999 'On Protection of Atmospheric Air'.	Sets out requirements for the provision of information on changes in atmospheric conditions (Art. 19, 23, 29)	Establishes requirements and standards for the quality of atmospheric air (Articles 11-19) Ensures control of impacts on atmospheric air (Article 21) Establishes the procedure for monitoring and controlling emissions of pollutants (Articles 23-26)
Federal Law No. 52-FZ of 30.03.1999 'On sanitary and epidemiological protection of the population'.	Establishes the procedure for ensuring the sanitary and epidemiological well-being of the population (Art. 2)	Establishes sanitary and epidemiological requirements for atmospheric air (Art. 20)
The Federal Law 'On Electric Power Industry' No. 35-FZ of 26.03.2003.	Establishes requirements for the provision of information on accidents in the electricity industry (Art. 28.5)	Establishes the principle of ensuring the environmental safety of the electricity industry (Art. 6)
Federal Law No. 190-FZ of 27.07.2010 'On Heat Supply'.	Establishes requirements for the provision of information on the activities of heat supply organisations (Art. 23.7)	Establishes the principle of ensuring the environmental safety of heat supply (Art. 3) Determines the development of heat supply systems taking into account the minimum harmful impact on the environment (Art. 23)

Sources: prepared by the authors on the basis of the Federal Laws 'On Environmental Protection" of 10.01.2002 No. 7-FZ, "On Atmospheric Air Protection' of 04.05.1999 No. 96-FZ, 'On Sanitary and Epidemiological Welfare of the Population' of 30.03.1999 No. 52-FZ, 'On Electric Power Industry' of 26.03.2003 No. 35-FZ, 'On Heat Supply' of 27.07.2010 No. 190-FZ.

[1] Decree of the Government of the Russian Federation dated 22.02.2012 N 154 'On requirements to heat supply systems, the procedure of their development and approval'. https://base.garant.ru/70144110/?ysclid=m82x2l2m82131373086.

[2] Except for the approval of the Master Plan in accordance with the procedure established by the legislation on urban development activities, changes in the period for which the Master Plan is approved, or in the event that the period of validity of the heat supply scheme (updated heat supply scheme) is less than 5 years. In such cases, a draft of a new heat supply scheme shall be prepared.

Approval of Heat Supply Schemes for Settlements, Urban Districts'[3] (hereinafter referred to as the Letter of RF Ministry of Energy), when developing and updating heat supply schemes it is recommended to include a section describing the current state of environmental impact 'Environmental safety of heat supply':

- an electronic map of the territory of a populated area showing the current location of all heat supply facilities;
- description of background or summary calculations of pollutant concentrations;
- description of the characteristics and quantities of fuels burned in heat supply installations;
- description of the technical characteristics of boiler units;
- description of gross and maximum single emissions of pollutants into the atmosphere from thermal energy sources;
- description of the results of calculations of the annual average concentrations of pollutants in the ground layer of atmospheric air from heat supply plants;
- description of the results of calculations of the maximum one-time concentrations of pollutants in the ground layer of atmospheric air from heat supply installations;
- description of the volume (mass) of the formation and emplacement of waste from fuel combustion;
- presentation of calculated data on the dispersion of pollutants from heat supply installations on a map of the settlement.

The letter from the Russian Ministry of Energy also lists pollutants for which it is recommended to provide a description of the gross and maximum one-time emissions into the atmosphere from thermal energy sources: sulphur dioxide, carbon monoxide, nitrogen oxides, benzo(a)pyrene, fuel oil ash calculated as vanadium, and solid particles. These pollutants are included in the list of pollutants, in respect of which state regulatory measures are applied in the field of environmental protection, and are presented in the Order of the Government of the Russian Federation dated 20.10.2023 No 2909-r[4].

Standards for maximum allowable concentrations (hereinafter referred to as MAC) of pollutants in the atmospheric air of urban and rural settlements are approved and presented in SanPiN 1.2.3685-21[5]. Standards for approximate safe reference levels of impact (hereinafter referred to as SRLI) have been approved for a number of substances. Table 2 presents the standards for MAC of pollutants in the atmospheric air, determined by the Ministry of Energy of Russia.

According to Paragraph 70 of SanPiN 2.1.3684-21, the hygienic standards for the content of pollutants in the air 1.0 MAC (SRLI) in residential areas and 0.8 MAC (SRLI) in the areas of health resorts, sanatoriums, rest homes, boarding houses, tourist centres, organised recreation of the population, beaches, parks, sports bases, long-term medical and preventive institutions and rehabilitation centres must not be exceeded[6].

In the Russian Federation, state monitoring of air quality is carried out at federal monitoring stations of the

Table 2
MAC standards for pollutants in the air of urban and rural settlements

Pollutant	MAC one-time (mg/m^3)	MAC d/a (mg/m^3)	MAC a/a (mg/m^3)	SRLI (mg/m^3)
Nitrogen dioxide NO_2	0.2	0.1	0.04	—
Nitrogen oxide NO	0.4	—	0.06	—
Sulfur dioxide SO_2	0.5	0.05	—	—
Carbon oxide CO	5.0	3.0	3.0	—
Benz(a)pyrene $C_{20}H_{12}$	—	0.000001	0.000001	—
Fuel oil ash	—	0.002	—	—
Inorganic dust with SiO_2 content of 20–70%	0.3	0.1	—	—
Coal ash	—	—	—	0.3

Source: prepared by the authors based on the analysis of SanPiN 1.2.3685-21.

[3] Letter of the Ministry of Energy of the Russian Federation dated 15.04.2020 No. MIO-4343/09 'On Approval of Heat Supply Schemes for Settlements and Urban Districts'. https://www.garant.ru/products/ipo/prime/doc/73896578/?ysclid=m82qcoua2x611919392.

[4] Decree of the Government of the Russian Federation dated 20.10.2023 N 2909-r 'On Approval of the List of Pollutants for Which State Regulatory Measures are Applied in the Field of Environmental Protection and on Recognition of Invalidity of Certain Decisions of the Government of the Russian Federation'. http://publication.pravo.gov.ru/document/0001202310230035?ysclid=m82qzlofoa566641787.

[5] Resolution of the Chief State Sanitary Doctor of the Russian Federation dated 28.01.2021 No. 2 'On Approval of Sanitary Rules and Regulations SanPiN 1.2.3685-21 'Hygienic standards and requirements for ensuring safety and (or) harmlessness of environmental factors for humans'. http://publication.pravo.gov.ru/Document/View/0001202102030022?ysclid=m82qqi3yaj304980243.

[6] Resolution of the Chief State Sanitary Doctor of the Russian Federation dated 28.01.2021 No. 3 'On Approval of Sanitary Rules and Regulations SanPiN 2.1.3684-21 "Sanitary and epidemiological requirements for maintenance of the territories of urban and rural settlements, water bodies, drinking water and drinking water supply, atmospheric air, soils, residential premises, operation of industrial, public premises, organisation and implementation of sanitary and anti-epidemic (preventive) measures"". . http://publication.pravo.gov.ru/Document/View/0001202102050027?ysclid=m82qkbxy2o246511165.

Roshydromet network (641 stations in 222 cities in 2023)[7]. In a number of cities, for example, pollution levels are also monitored at regional level:

- State Budgetary Institution 'MosEcoMonitoring' in Moscow (56 automatic stations)[8];
- SPb State Budgetary Institution 'Mineral' in St. Petersburg (25 automatic stations)[9];
- Krai State Budgetary Institution Center for the Implementation of Environmental Manage-ment and Environmental Protection in the Krasnoyarsk Territory (17 automatic stations)[10].

Requirements for monitoring the state of the environment are approved by Order of the Ministry of Natural Resources of Russia dated 30 July 2020 No 524[11].

Emissions of pollutants into the atmosphere from stationary sources are regulated by the state in accordance with Article 3 of the Decree of the Government of the Russian Federation dated 09.12.2020 No. 2055[12]. Heat supply installations shall comply with the following standards:

- maximum permissible emissions (standards for permissible emissions);
- technological emission standards;
- maximum permissible standards for harmful physical impacts on atmospheric air;
- technical emission standards.

Table 3
Number of heat supply sources in the Russian Federation in 2022 by capacity

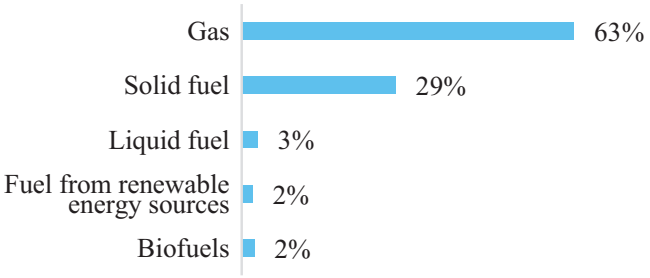
Heat supply source	Power	Number
Combined heat and power plants	< 25 thousand. kW	225
	> 25 thousand. kW	170
Boiler houses	< 3 Gcal·h	56876
	3–20 Gcal·h	13319
	20–100 Gcal·h	2453
	> 100 Gcal·h	598
Electric boilers, other	—	1180

Source: prepared by the authors on the basis of the report of the RF Ministry of Energy for 2022. https://minenergo.gov.ru/press-center/presentations/doklad-o-sostoyanii-teploenergetiki-i-tsentralizovannogo-teplosnabzheniya-v-rf-2022-?docs-group=file-295051.

According to the report of the Ministry of Energy of Russia 'On the state of thermal power engineering and centralised heat supply in the Russian Federation in 2022' (hereinafter referred to as the 'Report of the Ministry of Energy of Russia for 2022'), in 2022 there will be 395 combined heat and power plants and about 74.4 thousand boiler houses in the Russian Federation (Table 3)[13].

Heat supply sources in the Russian Federation use the following types of fuel: gas, solid fuel (coal, peat, pellets, etc.), liquid fuel, fuel from renewable energy sources and biofuel. The fuel structure of heat supply sources in the Russian Federation in 2022 is shown in Fig. 1.

Fig. 1. Fuel structure of heat supply sources in 2022 (%)



Source: prepared by the authors on the basis of the RF Ministry of Energy's report for 2022. https://minenergo.gov.ru/press-center/presentations/doklad-o-sostoyanii-teploenergetiki-i-tsentralizovannogo-teplosnabzheniya-v-rf-2022-?docs-group=file-295051.

According to the Information and Technical Handbook on Best Available Technologies ITS 38-2024 [Information and Technical Handbook, 2024], the main types of pollutants emitted into the atmosphere during the combustion of organic fuels in thermal power plants (hereinafter referred to as TPPs) are: sulphur dioxide, nitrogen oxides, carbon monoxide and solid fuel ash, and the greenhouse gas carbon dioxide CO_2. Other pollutants are also formed: benz(a)pyrene, soot, solid particles of unburned fuel.

The government has therefore established norms and standards aimed at minimising the negative impact of heat supply sources on the environment.

1. Literature review

Issues of the environmental safety of heat supply have been addressed repeatedly in the scientific literature.

A study by the National Research University 'MPEI' [Chekhranova, Gasho, 2020] analysed the operation of the Krasnoyarsk thermal power complex. The authors studied the possible effects of minimising the impact of the heat supply

[7] Review of the state and pollution of the environment in the Russian Federation for 2023. Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet). Moscow, 2024. https://www.meteorf.gov.ru/product/infomaterials/90/.
[8] https://mosecom.mos.ru/.
[9] https://mineral.kpoos.gov.spb.ru/.
[10] http://krasecology.ru/About/Index.
[11] Order of the Ministry of Natural Resources of Russia of 30 July 2020 N 524 'On Approval of Requirements for Monitoring the Condition of the Environment and Its Pollution'. http://publication.pravo.gov.ru/Document/View/0001202012140051?ysclid=m82qm4ko3s896194726.
[12] Decree of the Government of the Russian Federation dated 09.12.2020 N 2055 'On Maximum Permissible Emissions, Temporary Permissible Emissions, Maximum Permissible Standards for Harmful Physical Effects on Atmospheric Air and Permits for Emissions of Pollutants into Atmospheric Air'. http://government.ru/docs/all/131484/.
[13] Information and analytical report 'On the state of thermal power engineering and central heat supply in the Russian Federation in 2022', Ministry of Energy of the Russian Federation, 2023. https://minenergo.gov.ru/press-center/presentations/doklad-o-sostoyanii-teploenergetiki-i-tsentralizovannogo-teplosnabzheniya-v-rf-2022-?docs-group=file-295051.

system on the atmospheric air by increasing the supply of thermal energy from thermal power plants by redistributing the thermal load from boiler houses to thermal power plants with subsequent decommissioning or preservation of boiler houses. This practice is justified by the higher stacks of thermal power plants and the lower specific fuel consumption in the production of thermal energy, which has a positive effect on the volume and dispersion of emissions of pollutants from heat supply sources.

The work [Gasho et al., 2019] investigated the degree of influence of motor transport, production of thermal and electric energy at power plants and boiler houses on the ecological and climatic systems of Moscow. The authors found that the energy saving policy implemented in Moscow in terms of reduction of thermal energy losses led to an annual decrease in gas consumption at thermal energy sources by 7% in 2018, and a decrease in gross emissions of pollutants into the atmosphere of the city by 3.3 thousand tons/year.

The aforementioned works evaluated the effectiveness of specific measures aimed at reducing emissions of pollutants and minimising their concentration in the atmospheric air. It should be noted that currently there is no approved methodological approach to the issue of conducting a comprehensive assessment of the environmental safety of heat supply in cities, taking into account the requirements and methods defined by Orders of the Ministry of Natural Resources of Russia No. 273[14] (hereinafter referred to as Methodology No. 273) and No. 813[15] (hereinafter referred to as Methodology No. 813).

2. Research objective

On the territory of the Russian Federation there is a procedure of verification of computer programs for calculation of dispersion of emissions of pollutants in atmospheric air (except for emissions of radioactive substances) for compliance with Methodology No. 273 in accordance with Order No. 779 of the Ministry of Natural Resources of Russia dated 20.11.2009[16]. Within the framework of this work, the authors also proposed an analysis of existing calculation programmes and assessed the possibility of their integration to solve the complex problem of forming the 'Environmental safety of heat supply' section in heat supply schemes. The developed approach will be relevant for cities included in the experiment on quotas of pollutant emissions into the atmosphere within the framework of the federal project 'Clean Air' in accordance with the Resolution of the Government of the Russian Federation dated 07.07.2022 No. 1852-r[17].

The assessment of the environmental safety of the city's heat supply should be carried out in stages, taking into account the current requirements of legal acts and based on the principle of minimising manual data processing and calculations:

1) creation of a database of emission sources and monitoring posts;
2) entering data into certified calculation software (e.g., Integral, ECOcenter, Logus, ERA);
3) calculation of emissions and dispersion of pollutants taking into account external conditions (including meteorological conditions) using certified calculation software;
4) Creation of an electronic model of the impact of thermal power plants on atmospheric air using geoinformation software (hereinafter referred to as GeoPO);
5) Processing of the results of calculations of the dispersion of pollutants;
6) Creation of the project of the section 'Environmental safety of heat supply' for the heat supply scheme.

The first stage of the creation of a database of pollutant emission sources and air pollution monitoring stations includes the creation of registers of heat supply organisations, heat supply installations, heat generating installations and chimneys.

The second stage involves the transfer of data from the database to certified software that meets the requirements of the regulatory documents of the RF Ministry of Natural Resources. The certified software reflects the key attributes of all information objects, including fuel consumption, gas-air mixture characteristics and emission source parameters (height, pipe mouth diameter, presence of multi-barrel pipes).

The third step is to fill in the data and specify the parameters for the calculation:

– indicating meteorological characteristics and coefficients that determine the conditions for the dispersion of pollutant emissions into the atmosphere (based on data from a long-term observation period);
– indicating background concentrations of pollutants at background monitoring sites;
– selecting substances for calculation and background consideration
– indicating calculation areas with the introduction of calculation points;
– determining the dimensions of the calculated grid of the territory;
– forming layers (industrial, residential, safety, sanitary) with landfills.

The fourth stage involves the development of an electronic calculation model based on GeoPO. In this case, it is necessary to ensure the unloading of spatial data layers:

[14] Order of the Ministry of Natural Resources of Russia dated 06.06.2017 No. 273 'On Approval of Methods for Calculating the Dispersion of Emissions of Noxious (Polluting) Substances in Atmospheric Air'. http://publication.pravo.gov.ru/Document/View/0001201708110012?ysclid=m82qujzx7t214321841.

[15] Order of the Ministry of Natural Resources of Russia of 29 November 2019 No. 813 'On Approval of the Rules for Conducting Consolidated Calculations of Atmospheric Air Pollution, Including Their Updating'. http://publication.pravo.gov.ru/Document/View/0001201912260018?ysclid=m82qv8wd32613657367.

[16] Decision of the Ministry of Natural Resources of Russia of 20.11.2019 N 779 'On Approval of the Procedure for Conducting an Examination of an Electronic Computer Program for Calculating the Dispersion of Emissions of Pollutants in Atmospheric Air (Except for Emissions of Radioactive Substances)'. http://publication.pravo.gov.ru/Document/View/0001201912260037?ysclid=m82qw70jnt555713095.

[17] Order of the Government of the Russian Federation dated 07.07.2022 N 1852-r 'On Approval of the List of Municipalities and Municipal Districts with High and Very High Levels of Air Pollution, in Addition to the Territories of the Experiment on Pollutant Emission Quotas'. http://publication.pravo.gov.ru/Document/View/0001202207080032?ysclid=m82qxyl j1o596954812.

objects, chimneys, monitoring stations, calculation points, isolines of dispersion fields for each pollutant. In addition, sanitary protection zones (hereinafter referred to as SPZ), residential areas and specially protected natural areas (hereinafter referred to as SPNA) can be applied.

The fifth stage involves analysing the results of the calculations, including:

- presentation of the calculation results in the form of maps - diagrams of a populated area with isolines of the results of the calculation of the dispersion of pollutants;
- determination of the contribution of thermal energy sources to the concentration of pollutants at calculation points;
- determination of the thermal energy sources with the largest contribution to the concentration of pollutants in the ground;
- determination of pollutants exceeding the hygienic standards for the quality of atmospheric air by more than 0.8 MAC at points located within the boundaries of specially protected natural areas, and by more than 1 MAC at other calculation points.

In the sixth stage, a textual description of the results is produced, with conclusions structured in several sections: by heat supply organisations and facilities, by territorial division of the settlement, by pollutants, by monitoring stations and calculation points.

To validate the proposed approach, the efficiency is assessed, including the time and labour costs required to implement the stages of the proposed approach. In order to assess the efficiency of the decisions made at each stage, an experiment was conducted by comparing the time resources spent on implementation with and without the use of automation algorithms. The results of the experiment are described in the next section of this article.

3. Practical significance

The proposed approach was implemented using the example of the Moscow heat supply scheme for the two most relevant periods (updated for 2024 and 2025) to analyse the existing impact of thermal power plants on the air basin and climate of the city.

A total of 325 heat supply facilities included in the Moscow Heat Supply Scheme as of 01/01/2022 and 01/01/2023 were reviewed, including 687 emission sources (chimneys), 1278 pollution sources (boilers). To create the database, forms were sent to heat supply organisations for completion. Then the initial data were verified on the basis of the developed rules of format-logical control: establishment of confidence intervals for the parameters of pollution sources (height, pipe diameter, etc.), logical rules for calculated indicators (e.g. checking the gross values of pollutant and greenhouse gas emissions by the volume of fuel used and thermal energy supplied).

The initial data was loaded and processed using the PostgreSQL database management system (used in software products included in the Unified Register of Russian Programs for Electronic Computers and Databases, and is also part of the basic services of the Unified Digital Service of GosTech).

Based on the results obtained, a register of pollutant emission sources was compiled, which was used to calculate pollutant concentrations (Fig. 2).

The second stage of data collection involved transferring the data from the database to the certified 'Integral' calculation software.

The coding was introduced to ensure the information link of all sources along the following chain: organisation, object, chimney. For example, the chimney of TPP-23 of PAO Mosenergo was coded as OT312_T0003, where OT is the heat supply object, 312 is the serial number of the heat supply object in the register, T0003 is the serial number of the chimney.

The algorithm for the automatic input of data from the database into the certified software 'Integral' was developed in the Python programming language. In this way, the original database is independent of the certified software used to calculate the dispersion of pollutants. This approach makes it possible to minimise the number of errors when entering source data into the certified software and to reduce the time spent on updating and correcting data. It should be noted that certified software does not cover the full list of tasks specified in the recommendations of the Russian Ministry of Energy's letter, including the calculation of greenhouse gas emissions, management of production and consumption waste, and water discharges.

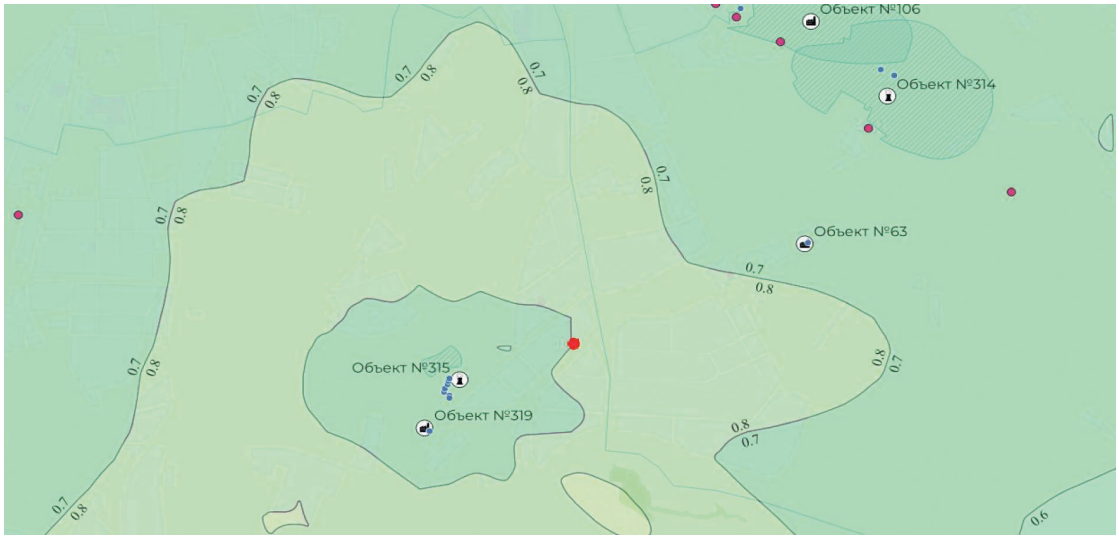
At this stage, time savings of up to 100 hours have been achieved by eliminating manual data transfer and the need for repeated checks.

In the third stage, preliminary and refined calculation of maximum one-time concentrations of pollutants and calculation of dispersion of pollutant emissions were carried out in the Integral software and calculation complex. One of the stages of the automated calculation was the introduction of meteorological characteristics and coefficients determining the conditions for the dispersion of pollutant emissions into the atmosphere. A short meteorological characteristic for Moscow was used as a source of data on meteorological conditions based on the observations of the meteorological station of the Federal Observatory of the Roshydromet network (FSBI Central UGMS).

Preliminary and refined calculations of ground-level concentrations have been made for the following pollutants and combinations of pollutant effects when present together in ambient air (summation effect):

- nitrogen dioxide (0301);
- nitrogen oxides (0304);
- carbon monoxide (0337);
- benz(a)pyrene (0703);
- sulphur dioxide (0330);
- fuel oil ash (for vanadium - 2904);
- nitrogen dioxide and sulphur dioxide (6204);
- all substances (combined result).

Fig. 2. Visualisation of a geo-information model showing heat supply facilities, pollutant emission sources, sanitary protection zones, residential areas, dispersion fields (isolines) and the results of the calculation of ground concentrations at control points



Source: compiled by the authors.

The results of the preliminary calculations were compared with the data from the monitoring stations of the federal network of Roshydromet to identify discrepancies, with the aim of adjusting the initial data for carrying out updated calculations of pollutant concentrations in accordance with Methodology No. 813.

At the next stage, an electronic model of the impact of thermal power plants on atmospheric air was created using GeoPO with open source code, on the basis of which it is possible to develop domestic software included in the Unified Register of Electronic Computers and Databases. The following layers were created in the geo-information model:

- calculation points: near thermal power plants, federal monitoring stations of the Federal State Budgetary Institution 'Central UGMS', regional monitoring stations of the State Budgetary Institution 'MosEcoMonitoring', on the border of protected zones, on the border of the sanitary protection zone;
- zones: industrial, residential, safety and health protection zones;
- pollutant emission sources;
- sources of heat supply;
- results of pollutant dispersion calculations in the form of isolines.

The developed model was formed as an independent single geoinformation file, which allows interactive visualisation of the spatial distribution of pollutants in the atmosphere. To create the model, an algorithm was used that included processing and transfer of the generated results from the Integral software and calculation complex to GeoPO. This model can also be integrated into an electronic model of a heat supply system, including for the formation of electronic models of heat supply systems (ZuluThermo, CityCom, etc.). An example of a visual representation of the modelling results is shown in Fig. 2.

By automating this stage of the process, time savings of up to 50 hours per iteration of the data visualisation and presentation process have been identified.

The stage of processing the results of the dispersion calculations involved the following types of work:

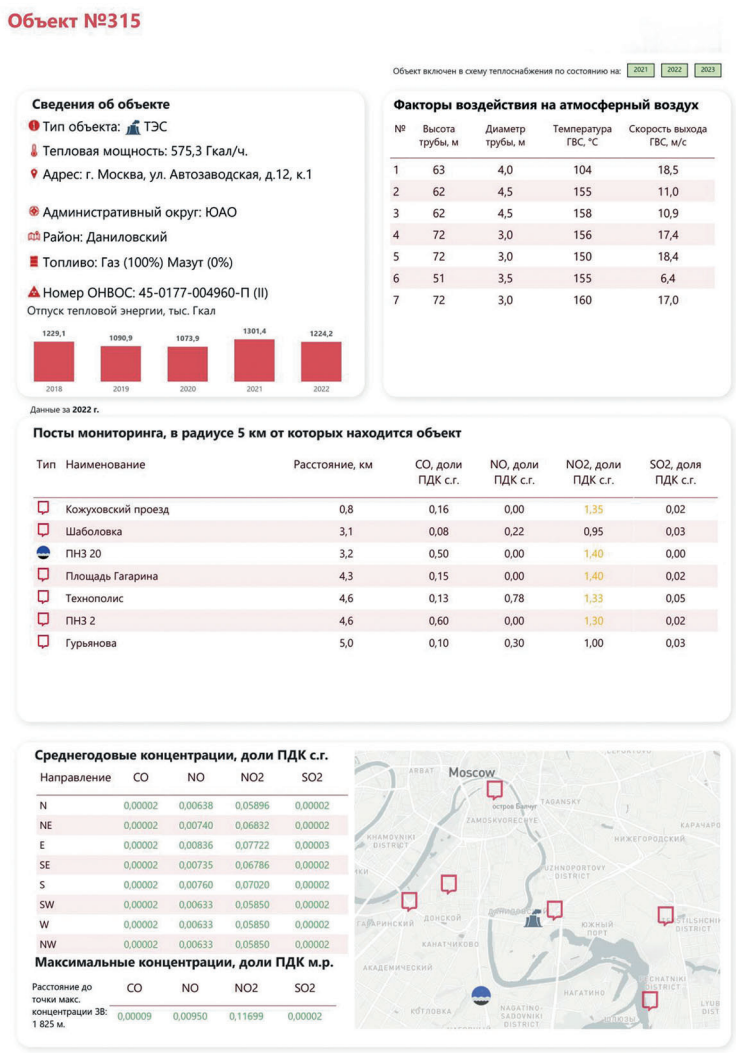
- development of an algorithm to automatically process the results of pollutant dispersion calculations;
- entering the results into the database;
- creation of passports for heat supply facilities with information on each facility, including its characteristics, technical parameters and the nearest air monitoring stations (Fig. 3);
- monitoring station passports containing information on the location of the stations, the pollutants monitored and their concentrations in the air (Fig. 4).

The draft text of the section 'Ecological safety of heat supply' of the heat supply scheme can be created using the Report Designer of Cycle-On LLC - Thermo Carb-On, which enables the generation of a textual description of the calculation results in relation to the database. Using Moscow as an example, the final section contains 325 facility passports, 68 monitoring station passports, analyses for 12 administrative districts, including analyses for facilities outside Moscow, analyses for 4 substances and summation groups for which emissions from heat supply facilities are formed, and for 143 reference points.

By automating the processing of dispersion calculation results and text generation, it is expected that up to 80 hours of data processing and text generation time will be saved.

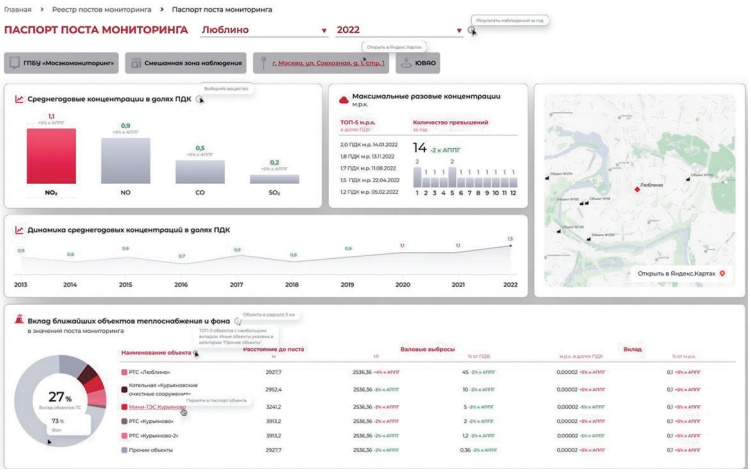
Table 4 presents tools for automating processes to reduce the labour costs of conducting a comprehensive assessment of the environmental safety of heat supply, using Moscow as an example.

Fig. 3. Facility certificate



Source: compiled by the authors.

Fig. 4. Example of a surveillance pass



Source: compiled by the authors.

Table 4
Effects of automating the stages of complex environmental assessment on the example of Moscow

Stages		Impacts	
№	Stage name	Time saving (hours per 1 iteration)	Description of the impact
1	Collecting and systematising the data received	100	The need for manual data entry and aggregation is eliminated, data format errors and technical errors are minimised
2	Automating the input of information from the database into the Integral calculation software	40	The need for manual data entry when transferring to certified software is eliminated
4	Creating an electronic model of the impact of thermal power plants on atmospheric air	50	The need to manually consolidate dispersion calculation results into a single geoinformation model (a layer for each substance and each calculation grid) is eliminated
5	Processing the results of calculations of pollutant dispersion	20	The need for manual processing of results, aggregation of results is eliminated
6	Formation of the project of the section ‘Environmental safety of heat supply’.	60	The labor costs for writing a text description of calculation results and the costs of processing the description when updating data and calculations are minimised

Source: compiled by the authors.

Conclusions

At present, there is no approved methodological approach for implementing the recommendations of the Russian Ministry of Energy on making a comprehensive assessment of the environmental safety of heat supply systems for populated areas.

Within the framework of this article an approach to the formation of the section ‘Ecological safety of heat supply’ of heat supply schemes is proposed, taking into account the recommendations of the Ministry of Energy of Russia, including the use of automated algorithms. Testing of the approach on the example of the Moscow heat supply system allowed

to create a scalable toolkit for assessment of ecological safety of heat supply in cities.

The proposed methodological approach can be used in the development of heat supply schemes in cities that are obliged to develop and update an electronic model of the heat supply scheme. The approach can also be used in the work of state and municipal authorities in connection with the preparation of the order for the development and updating of heat supply schemes, and in carrying out procedures for their coordination and approval. The proposed approach is particularly relevant for cities included in the experiment on quotas for emissions of pollutants into the atmosphere within the framework of the federal project 'Clean Air'.

As a further development of this study, it is also possible to develop automated software products that allow the formation of the 'Environmental safety of heat supply' section, including through integration with certified computer calculation programs that calculate the dispersion of pollutants according to Method No. 273.

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