Study of changes in emissions into the atmosphere with the reconstruction of heat supply systems

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Abstract. In today's world, environmental issues are becoming increasingly important and relevant. The housing and communal services system is often one of the main sources of anthropogenic impact. So, when receiving thermal energy by burning of organic or mineral fuel, various types of pollutants enter the atmospheric air. In this paper, a comparison of gross emissions into the air during operation of a heat source using fuel oil and wood fuel (pellets) is made. An analysis of the results was carried out. It showed that the most “environmentally friendly” are heat sources, the main equipment of which includes boiler units burning wood fuel (pellets). With the operation of this type of boiler, the level of anthropogenic load in the form of pollutants emissions is significantly reduced, in particular, there is a multiple decrease in emissions of pollutants of hazard class III.

1. Introduction
Currently, on the territory of the Russian Federation, the infrastructure of the housing and communal services system has a high degree of moral and physical deterioration. This fact indicates the need for reconstruction of many objects of the heat supply system. In modern socio-economic conditions, the key factor determining the need for the implementation of innovative projects is not only technical and economic indicators, but also environmental ones. So, when choosing the main equipment of sources (for example, boiler units) in heat supply systems, such criteria as the cost of equipment are considered; efficiency and flow rate of resources to ensure their work; the unit cost of the generated target product (thermal energy), taking into account the fuel and amortization components; the range of regulation of equipment power without a significant reduction in efficiency [1]. In addition to technical and economic indicators, environmental aspects play a significant role. The main types of negative impact of heat supply system facilities are emissions of pollutants into the atmosphere [2]. As is known, the main factor determining the quantitative and qualitative composition of emissions is the type and properties of the burned fuel [3,4].

In connection with the latest changes in environmental legislation, the state of the environment and the factors of negative impact are receiving increasing attention [5-9]. All of the above necessitates the research presented in this article.

2. The relevance of research
Modern requirements in the sphere of environmental safety determine the conduct of research in the field of improving the quality of environmental protection in reconstruction of heat supply systems. In addition, given the natural value of the Irkutsk region, due to its location near the Lake Baikal, technical solutions that have an environmental advantage are priority tasks in modern conditions.

3. Content statement of the problem and initial data
A study of impact of replacing the main equipment of the heat source when the reconstruction of the heat supply system for one of the settlements of the Irkutsk region on the change in harmful emissions into the environment was carried out.

The reconstruction of the heat source of the heat supply system consisted in the replacement of the hot water boiler KVA 3.0 G / L [10], which runs on liquid fuel (fuel oil), with the Pyrolysis Master boiler, industrial series PELLET PRO [11], which runs on wood fuel (pellets). The characteristics of the working fuel of boiler units are given in table 1.

| Indicators                      | Fuel oil  | Pellets |
|--------------------------------|-----------|---------|
| Ash, %                         | 0.03      | 1.5     |
| Sulfur content (total), %       | 1.22      | 0.03    |
| Nnet calorific value, MJ / kg   | 38.77     | 17.316  |

To estimate the calculation variants, the main environmental criterion was used. It is gross emissions of harmful emissions into the air. The calculation of gross emissions was carried out for two variants of fuels for heat source: 1) liquid fuel (fuel oil); 2) wood fuel (pellets).

Calculation of gross emissions was carried out using the «Methodology for determining of pollutants emissions into the atmosphere when burning fuel in boilers with a capacity of less than 30 tons of steam per hour or less than 20 Gcal per hour» [12,13]. When calculating gross emissions fuel combustion indicators are taken into account. These indicators are given in table 2.

| Indicators                        | Fuel oil  | Pellets |
|----------------------------------|-----------|---------|
| Heat loss from mechanical incomplete combustion q₄, % | 0.08      | 0.5     |
| Heat loss due to chemical incomplete combustion of fuel q₃ (о6μμ), % | 0.2      | 0.5     |
| Flue gas recirculation rate r, % | 0         | 0       |
| The sulfur content of the fuel on the working mass Sr, % | 1.22      | 0.03    |

4. Numerical research
To estimate the degree of negative impact on the atmospheric air, a comparison of the gross emissions of pollutants was made. The calculation results for the two variants of fuels used on the heat source are shown in table 3.

| Indicators                      | Fuel oil  | Wood fuel (pellets) |
|--------------------------------|-----------|---------------------|
| Heat loss from mechanical incomplete combustion q₄, % | 0.08      | 0.5     |
| Heat loss due to chemical incomplete combustion of fuel q₃ (о6μμ), % | 0.2      | 0.5     |
| Flue gas recirculation rate r, % | 0         | 0       |
| The sulfur content of the fuel on the working mass Sr, % | 1.22      | 0.03    |
| Code | Emission name | Gross emission (t / year) with operation of a fuel oil boiler | Gross emission (t / year) with operation of a pellet boiler |
|------|---------------|-------------------------------------------------------------|----------------------------------------------------------|
| 0301 | Nitrogen (IV) oxide (Nitrogen dioxide) | 5.422760 | 0.973138459 |
| 0304 | Nitrogen (II) oxide (Nitrogen oxide) | 0.881199 | 0.158135 |
| 0330 | Sulfur dioxide (Sulphurous anhydride) | 35.114772 | 0.051377 |
| 0328 | Carbon (Soot) | 1.393727 | - |
| 0337 | Carbon oxide | 7.395466 | 0.867846 |
| 0703 | Benz / a / pyrene (3, 4-Benzpyrene) | 0.00000143689 | 0.000201881 |
| 2902 | Suspended matter | - | 0.266893 |
| 2904 | Fuel oil ash of thermal power plants (in terms of vanadium) | 0.092996 | - |

An analysis of the data showed that a significant reduction in gross emissions is noted when using a pellet boiler. When using a fuel oil boiler, more than 35 tons of sulfur dioxide enter the atmospheric air annually. When using wood fuel (pellets), nitrogen dioxide is the main to air pollution.

A feature of environmental performance assessment is the need to take into account the degree of hazard of the emitted substances. Thus, it is more expedient to compare the amount of substances emitted, based on the degree of their danger to human health, which was done at the next stage of numerical studies. So, extremely dangerous substances (having a carcinogenic risk) carry the maximum danger, i.e. substances of hazard class I, and substances of hazard class IV are of low hazard [14].

Thus, taking into account the hazard classes of all substances (given in the Hygienic Standards [14]), it should be noted that when using fuel oil and wood fuel (pellets), substances belonging to hazard classes III and IV are released into the atmosphere. However, when using wood fuel (pellets), their amount is several times less than when using fuel oil. So, for example, when burning fuel oil, more than 42 tons of hazard class III substances will be released into the atmosphere annually, and when burning wood fuel (pellets) – 1.4 tons annually. Figures 1 and 2 show a graphical representation of the distribution of emissions of hazard classes III and IV for different types of fuels.

**Figure 1.** Diagram of total gross emissions with operation of a fuel oil boiler (t/year)

**Figure 2.** Diagram of total gross emissions with operation of a pellets boiler (t/year)

The total indicator of gross pollutant emissions is:

- when using fuel oil as fuel it is more than 50 tons per year with a predominance of emissions of hazard class III;
- when using wood fuel (pellets) it is 2.3 tons per year, while the share of pollutants of hazard class III is reduced by almost 30 times.
Thus, the analysis of the obtained during the numerical studies results of the distribution of gross emissions of harmful substances showed that when using of boilers for various fuels for heat source wood fuel (pellets) is the most «environmentally friendly».

5. The practical relevance of experimental research

In this work, the efficiency of using boiler on wood fuel (pellets) is shown using a example of a real heat supply system. The obtained results proved that during the operation of pellet boilers, the level of anthropogenic load in the form of pollutant emissions decreases significantly.

The decrease in gross emissions indicates the environmental and economic efficiency of the reconstruction of the investigated energy object. So, with a decrease in gross emissions into the atmosphere, firstly, environmental damage for the environment is directly reduced and, secondly, there is a reduction in payments of enterprises for negative impact. Thus, the transition to the use of wood-burning (pellets) boilers at heat sources will reduce the negative impact on the environment, and enterprises operating housing and communal services will reduce the financial costs of the environmental component.

6. Conclusions

The calculation method proved the feasibility of reconstructing of heat supply system with the transfer of the heat source from fuel oil to wood fuel (pellets). The environmental and economic efficiency of the use of pellet fuel is due to a decrease in gross emissions of pollutants into the atmosphere. The results showed that during the operation of a pellet boiler, there is reduction in emissions of pollutants of hazard class III by 30 times compared with a fuel oil boiler.

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References

[1] Khan V.V. 2016 University News. Investments. Construction 4 (19) p 146 [In Russian]
[2] H. Zhou, Q. Yang, Sh. Zhu, Y. Song, D. Zhang 2019 Resources, Conservation and Recycling 144 p 74
[3] Hu Wang, Xumin Zhao, Laihui Tong, Mingfa. 2018 Fuel 227 p 457
[4] H. Chen, J. He, X. Zhong. 2018. Journal of the Energy Institute, corrected proof [In press]
[5] Federal Law of July 21, 2014 N 219-FZ (as amended since January 1, 2020) [In Russian]
[6] Federal Law of January 10, 2002 N 7-FZ (as amended from January 1, 2020) [In Russian]
[7] Federal Law of May 4, 1999 N 96-FZ (edition as of November 1, 2019) [In Russian]
[8] Lavygina OL, Grebneva OA. 2019 University News. Investments. Construction 9(4) p 726 [In Russian]
[9] Olga Lavygina, Oksana Grebneva, and Irina Maizel 2019 IOP Conf. Series: Materials Science and Engineering 667 012056
[10] KVA-3.0 boiler characteristic (KVA-3.0-95 boiler) http://www.energokomplekt.net/kotel-kva-3.pdf [In Russian]
[11] Boiler catalog of Pyrolysis Master https://pirolizmaster.ru/kotly/ [In Russian]
[12] Method of Determining Atmospheric Emissions of Pollutants Produced by Burning Fuel in Boilers Having Capacity of 30 t/h of Steam or Less Than 20 GCal/h 1999 ( Moscow: State Committee for Ecology of Russia)
[13] Method for calculating, standardizing and controlling emissions of pollutants into the atmosphere (supplemented and processed) 2012 (St. Petersburg: Research Institute Atmosphere) GN 2.1.6.3492-17 2017