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Air Pollution by Heat Supplying Enterprises of Nalchik

Sozaeva Lezhinka Tanashevna
Department of clouds' physics
High-Mountain geophysical institute
Nalchik, Russian Federation
ljk_62@rambler.ru

Shungarov Islam Khasanovich
Faculty of physics and mathematics and natural Sciences
Peoples' Friendship University of Russia
Moscow, Russian Federation
sozaev.islam@mail.ru

***Abstract*—This paper presents the maximum single and annual emissions of pollutants into the atmosphere from heating enterprises in Nalchik. The results of calculations of the dispersion of pollutants at the control points (residential living areas nearest to heating houses) are given. It is shown that the surface concentrations of nitrogen oxides and carbon monoxide at the control points do not exceed maximum permissible concentration not taking into account and taking into account background pollution.**

***Keywords*—ground concentrations of pollutants; nitrogen oxides; carbon oxide; maximum permissible concentration; heating house**

I. Introduction

One of the urgent problems of our time is air pollution, which, by changing its composition and properties, has a negative impact on human and animal health and the state of plants. Pollution of the atmosphere results in acid rain and smog, which can also lead to the death of all living things, causing many diseases. Pollutants, penetrating into the human body, have a negative impact on the work of internal organs, mucous membranes, immunity, cause the growth of cancer.

In addition, pollutants have a tendency to retain heat in the atmosphere, causing the increase of the surface temperature of the planet, what contributes to global warming, which can lead to melting of glaciers, rising of water levels, etc. Pollutants also play an active role in the processes of formation and destruction of the ozone layer of the atmosphere, which absorbs the hard ultraviolet radiation of the sun.

According to data on global air pollution, carbon oxide (500 million tons), sulfur dioxide (150 million tons), oxides of nitrogen (50 million tons), methane (110 million tons), hydrocarbons (90 million tons) are emitted into the atmosphere every year [1].

In the Russian towns, the main sources of anthropogenic air pollution are motor transport (32%), heating and industrial boilers (24%), metallurgy (26%), oil production and oil refining (13%), chemical industry (2%) and others (3%) [2].

This paper considers air pollution at the local level, using the example of Nalchik, located in southern Russia. Air pollution on the territory of the town is caused by industrial enterprises, heat-generating plants (industrial and heating houses), motor transport, production of building materials and fuel-filling stations. Nowadays, a significant portion of emissions conditioned by the processes of combustion of natural gas, falls to the share of urban heating houses. When burning natural gas, nitrogen oxides and carbon monoxide, which are among the most common pollutants, are released into the atmosphere. In nitrogen emissions, the main part (80%) is nitrogen dioxide, and nitrous oxide accounts for 13(%). Incomplete combustion of carbon dioxide is formed. Emissions are influenced by quality [3, 4].

In order to calculate the characteristics of emissions of pollutants (nitrogen oxides and carbon oxide) from heat supplying enterprises of Nalchik, an inventory of emission sources was carried out. The negative impact of emissions was estimated using the results of calculations of maximum ground concentrations of pollutants created by emissions from heating houses at the boundary of the living zone.

II. Methods and materials

Heating enterprises of Nalchik are specialized on the production of steam and hot water (heat energy) houses, hospitals, schools, kindergartens and enterprises. They consist of 64 boilers separated in the urban district, in which 208 boilers are operated. According to the inventory, there are 102 sources of air pollution in the city. Emission of pollutants (oxides of nitrogen and carbon oxide) is realized through funnel chimneys of various height. Pollutants are emitted through chimneys of different heights and diameters.

At the first stage, emissions of pollutants according to the program product of series "Eco Center" were approved by the "Atmosfera" Research Institute. In this program the method for determining emissions of pollutants into the atmosphere during fuel combustion in boilers was realized [5].

The total amount of nitrogen oxides emitted into the atmosphere with flue gases is calculated by the formula [5]:

$$M_{NOx} = 0.001\ Bp\ Q\ K\ \beta_k\ \beta_t\ \beta_\alpha\ (1—\beta_r)\ (1—\beta_\delta), \qquad (1)$$

where B_p – rate of fuel consumption, [l/s, thousand m^3/year]; Q – lower heating value of fuel [mega joules/m^3]; K – specific emission of oxides of nitrogen at gas combustion, [g/mega joules]; β_k – dimensionless coefficient that takes into account

basic construction of the burner; β_t – dimensionless coefficient that takes into account air temperature for combustion; β_α – dimensionless coefficient that takes into account the influence of recirculation of air excess on formation of oxides of nitrogen; β_r – dimensionless coefficient that takes into account the influence of recirculation of chimney gases through burners on formation of oxides of nitrogen; β_δ – dimensionless coefficient that takes into account stepwise airing in combustion chamber.

Taking into account the transformation of nitrogen oxides in atmospheric air, emissions of nitrogen dioxide and nitrogen oxide are determined by the formulas:

$$M_{NO2} = 0.8\ M_{NOx} \text{ and } M_{NO} = 0.13\ M_{NOx}.$$

The total emissions of carbon oxide is realized according to the ratio [5]:

$$M_{CO} = 0.001\ B\ C_{CO}\ (1—q_4/100), \quad (2)$$

where B – rate of fuel consumption, [l/s, thousand m^3/year]; C_{CO} – outflow of carbon oxide at fuel burning, [g/m^3]; q_4 – egress of heat as a result of mechanic incompleteness of fuel burning, [%].

The annual emissions are measured in tones/year, and maximum one-time emissions – in g/sec.

At the second stage, to evaluate the level of negative impact of pollutants on atmospheric air the analysis according to the program "Ecogol-4.5" certified in accordance with the established standards, which realizes methods of calculation of pollutants emission in the atmospheric air [6, 7], was carried out.

These methods allow calculating maximum one-time ground concentrations which correspond to combination of unfavorable meteorological conditions and unfavorable conditions of emission in the atmosphere, i.e. such combination of parameters of pollutants emission in the atmosphere when ground concentrations reach their maximum.

Maximum rates of one-time ground concentrations are determined using the following formula:

$$C = A\ M\ F/(H2\ (V\ \Delta T)1/3), \text{ [mg/m}^3\text{]} \quad (3)$$

where M – maximum one-time emission of pollutants in the atmosphere per time unit, [g/s]; $A=200$ – coefficient corresponding to unfavorable meteorological conditions when pollutant concentration in the atmosphere is maximum; F – dimensionless coefficient that takes into account settling rate of pollutants in the atmospheric air; H – the height of the source of emission (funnel chimney) above the ground surface, [m]; ΔT – difference between temperature of emitted steam mixture and temperature of atmospheric air, [^{0}C]; V – steam-gas mixture flow rate, [m^3/sec], (is determined by nameplate data of boilers – temperature of gases, fuel consumption per time unit).

The degree of negative impact of emissions on atmospheric air is estimated by the following criterion:

$$C_j/MPC_j + C_{bj}/MPC_j \leq 1, \quad (4)$$

where C_j – maximum ground one-time concentration of j-pollutant formed by emission of the source of air pollution on the boundary of the living area, [mg/m^3)]; MPC_j – maximum permissible concentration of j-pollutant in the atmospheric air of the populated areas, [mg/m^3]; C_{bj} – background concentration of j-pollutant which is taken into account in case if the first term of the sum (formula 4) is more than 0.1. For the enterprises located in the resort area the right part of a formula (4) is equated to 0.8.

Meteorological characteristics that determine conditions of dispersion of pollutants in the atmosphere in the area of the enterprise location are requested in the authorities of the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet) or are determined according to climate data published for general access in the Internet [8].

The citywide level of background pollution is requested in the authorities of Roshydromet or determined by temporary recommendations.

To make detailed analysis of emissions the dimensions of region of computation of the zone of influence of emissions of the enterprise and grid spacing were set. Calculated points were selected on the nearest living areas. For each grid node and for calculated points located in the nearest living area maximum ground concentrations of pollutants with the help of sorting speeds and directions of wind, were determined. Wind speeds were sorted from 0.5 m/sec to the wind speed, excess frequency of which is 5% according to perennial data for the given location. Wind direction changes on the whole diapason from 0 to 360 grades with the interval of 1 grade.

Observance of hygienic criteria of atmospheric air quality (4) was examined in calculated points.

The following meteorological parameters are characteristic of the city of Nalchik [8]:

- the average maximum air temperature of the hottest month is equal +27.5^{0}C;
- the average temperature of the coldest winter month is around - 6.50C;
- wind speed, the frequency of excess of which according to long-term data is 5%, is equal 6 m/s.

The degree of background pollution for the nitrogen dioxide is 0.079 mg/m^3 [9].

Maximum permissible concentrations of polluting substances according [10] are equal for:

- nitrogen dioxide – 0.2 mg/m^3;

- oxide of nitrogen – 0.4 mg/m^3;
- carbon oxide – 5 mg/m^3.

III. THE RESULTS OF CALCULATIONS OF POLLUTANTS' EMISSIONS INTO THE ATMOSPHERE

Calculations of emissions of pollutants in the atmosphere have shown that at a total consumption of natural gas of 124 million m^3/year, emissions of pollutants in the atmosphere by heating enterprises were 741.634 tons/year [11].

Among them: nitrogen dioxide – 253.008 tones/year, oxides of nitrogen – 41.096 tones/year, carbon oxide – 447.530 tones/year. The list of the pollutants emitted into the atmosphere for 22 more powerful heating houses is presented on Tab. I.

By the degree of atmospheric pollution, carbon oxide goes ahead, then - nitrogen dioxide and oxides of nitrogen, correspondently. Oxides of nitrogen belong to the third class of hazard and carbon oxide - to the forth class.

From Tab. I it is obvious that the amount of pollutants is proportional to the power of the heating house and natural gas-flow rate.

TABLE I. THE LIST OF THE POLLUTANTS EMITTED INTO THE ATMOSPHERE FROM HEATING ENTERPRISES OF NALCHIK

The name of the heating house	**Thermal power of heating houses, [Gcal/hour]**	**Natural gas flow rate, [thousand m^3/year]**	**Maximum one-time emission, [g/sec]**			**Annual emission of polluting substances, [tones/year]**		
			Oxides of nitrogen	*Nitrogen dioxide*	*Carbon oxide*	*Oxides of nitrogen*	*Nitrogen dioxide*	*Carbon oxide*
The south-western	140	29640	0.95	5.83	7.19	14.06	86.53	105.75
Nart	16.6	3651	0.078	0.48	0.9	1.14	6.9	13
Gorbolnitsa	9.24	883	0.01	0.67	0.18	0.19	1.17	3.15
Pushkin	19.56	5711	0.18	0.72	1.36	1.73	10.62	20.34
Pachev	15.66	3252	0.04	0.26	0.68	0.73	4.48	11.55
Nogmov-45	9	1783	0.03	0.19	0.48	0.4	2.49	6.36
Nogmov-70	6	1172	0.03	0.17	0.42	0.28	1.73	4.17
Tolstoi	24.9	4753	0.08	0.48	0.96	1.38	8.46	16.95
Iskozh-2	18.6	5557	0.09	0.56	1.31	1.37	8.44	19.79
Musukaev	12	3935	0.05	0.33	0.82	0.9	5.78	14.07
DVTU	13.5	4083	0.07	0.42	0.96	1.03	6.33	14.55
9 January	170	22236	0.30	1.82	1.79	8.79	47.29	79.74
Mechnikov	6	994	0.01	0.09	0.23	0.23	1.38	3.54
Lenin	10.5	2190	0.06	0.36	0.87	0.88	5.42	13.01
Tubdispancer	15.5	5140	0.12	0.74	1.38	1.53	9.39	18.32
Kalmykov	24.9	9038	0.14	0.92	1.63	2.9	17.85	32.21
Profsoyuznaya	7.6	1338	0.02	0.12	0.31	0.29	1.75	4.77
Melikyants	19.5	3756	0.07	0.42	0.86	1.06	6.52	13.38
Giprozem	9	1526	0.05	0.29	0.70	0.37	2.25	5.44
Gagarin- 2	4	989	0.02	0.10	0.24	0.23	1.38	3.52
Gagarin-203	4.5	1058	0.04	0.22	0.51	0.27	1.67	3.77
Telman-Krylov	6	1099	0.02	0.12	0.30	0.25	1.54	3.92

IV. THE RESULTS OF CALCULATIONS OF POLLUTANTS' DISPERSION IN THE ATMOSPHERE

We will consider calculation of dispersion of pollutants in the atmosphere on the example of a "Nart" heating house. The situational map of the region of an arrangement of this heating house is presented in Fig. 1. The enterprise is near the resort park in the central part of the town crossing of streets of Shogentsukova and Lermontov.

The source of air pollution №0001 (SAP №0001) is the chimney of 38 m high and with a diameter of 1.2 m through which pollutants, during combustion of natural gas in furnace cameras of coppers, emit to the atmosphere.

At the distance of 35 m from a source of pollution there is a building of "Nalchik" hotel, at the distance of 50 m – the living house, at the distance of 70 m – the kindergarten (Fig. 1). The calculation of atmospheric air pollution was realized on the areas with a width of 300 m and with a step of 10×10 m. The calculated points (CP) have been chosen on the boundary of the "Nalchik" hotel (CP №1), the living house (CP №2) and the kindergarten (CP №3).

The calculations of dispersion of pollutants in the area of the heating house location showed that nitrogen dioxide at the boundary of the living areas creates maximum ground level concentrations of 0.26·MPC at CP №3 (Fig. 2), nitrogen oxide – 0.02·MPC and carbon monoxide – 0.02·MPC.

A breakdown wind speed is 0.65 m/s.

The nitrogen dioxide on the boundary of a living area creates concentration 0.65·MPC on the CP №3 (Fig. 3) taking into account background pollution. For nitrogen oxide and carbon oxide, the background pollution is not considered since in a formula (4) the first term of the sum is less than 0.1. It should be noted that the maximum ground concentrations created by the source in the area of location of "Nart" heating

house do not exceed 0.3·MPC on dioxide of nitrogen and 0.02·MPC on nitrogen oxide and carbon oxide.

Calculations are carried out taking into account that this heating house is near the resort area (the right part of a formula (4) is equal to 0.8).

The similar calculations which are carried out for all other heating houses have shown that the maximum ground level concentration of pollutants in calculated points (on the boundary of a living area) don't exceed threshold limit values without accounting and taking into account background pollution (Tab. II).

On the boundary of a living area without taking into account background pollution of concentration of nitrogen oxide and carbon oxide make (0.01÷0.06)·MPC, dioxide of nitrogen – (0.01÷0.59)·MPC.

For the enterprises for which nitrogen dioxide creates a concentration of more than 0.1·MPC in the living area, calculations were carried out taking into account the background pollution. It turned out that in these cases on the boundary of a living area, dioxide of nitrogen creates concentration (0.45÷0.75)·MPC, not exceeding MPC (Tab. II).

This indicates the compliance of hygienic standards of quality of atmospheric air for pollutants emitted by heating enterprises of Nalchik town [10].

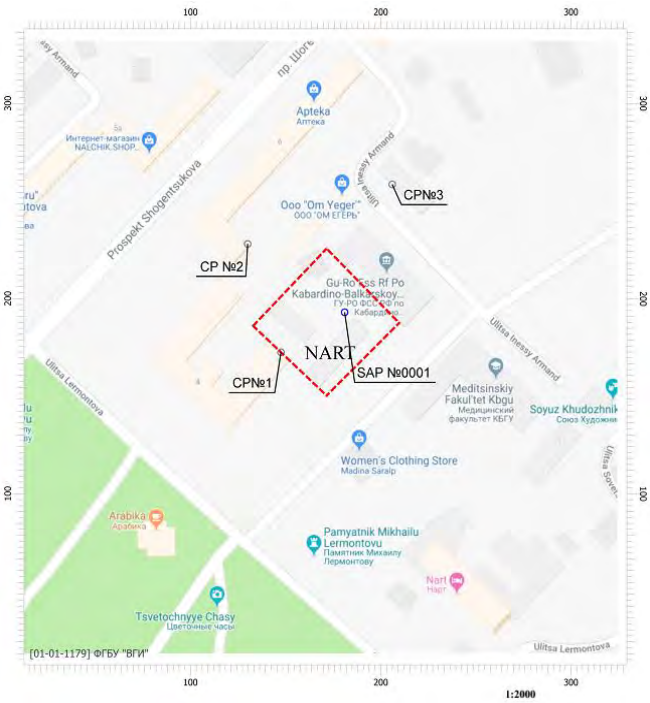

Fig. 1. The situational map of the location of "Nart" heating house: dotted line – areas of the heating house; CP – calculated point; SAP – source of air pollution.

Fig. 2. The map of dispersion of dioxide of nitrogen without the background pollution: dotted line – areas of the heating house; CP – calculated point; SAP – source of air pollution.

Fig. 3. The map of dispersion of dioxide of nitrogen with the background pollution: dotted line – areas of the heating house; CP – calculated point; SAP – source of air pollution.

TABLE II. THE MAXIMUM GROUND CONCENTRATION OF THE POLLUTANTS IN THE BOUNDARY OF THE LIVING AREA

The name of the heating house	**The maximum ground level concentration, [p·MPC]**			
	Without the background pollution			**With the background pollution**
	Oxides of nitrogen	*Nitrogen dioxide*	*Carbon oxide*	*Oxides of nitrogen*
The south-western	0.02	0.3	0.01	0.57
Nart	0.02	0.25	0.02	0.65
Gorbolnitsa	0.02	0.23	0.03	0.53
Pushkin	0.04	0.46	0.03	0.67
Pachev	0.02	0.31	0.03	0.58
Nogmov-45	0.01	0.15	0.02	0.49
Nogmov-70	0.02	0.22	0.02	0.52
Tolstoi	0.02	0.26	0.02	0.55
Iskozh-2	0.05	0.59	0.06	0.75
Musukaev	0.04	0.48	0.05	0.68
DVTU	0.03	0.37	0.03	0.62
9 January	0.03	0.35	0.03	0.61
Mechnikov	0.03	0.38	0.03	0.60
Lenin	0.03	0.36	0.03	0.61
Tubdispancer	0.03	0.38	0.03	0.62
Kalmykov	0.03	0.38	0.03	0.63
Profsoyuznaya	0.02	0.2	0.02	0.52
Melikyants	0.02	0.22	0.02	0.53
Giprozem	0.01	0.15	0.01	0.49
Gagarin- 2	0.03	0.31	0.03	0.58
Gagarin-203	0.03	0.32	0.03	0.58
Telman-Krylov	0.01	0.13	0.01	0.47

V. CONCLUSION

Calculations of dispersion of polluting substances have shown that their concentration on the boundary of a living area for each heating house does not exceed maximum permissible rates of these substances.

However, heating enterprises of the single Nalchik town emit a significant amount of pollutants which are necessary to reduce.

Emission reduction may be realized by using ecologically pure natural gas or fuel purification before combusting, purification of end product of fuel combustion (final steam gases) and regulation of the mechanism of fuel combustion in the combustion chamber, or using alternative sources of energy.

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