UDC 504.064

DOI: 10.15372/KhUR20160403

Black Carbon, Soot and Dust Particles in the Atmosphere of an Industrial City

S. V. MIKHAILUTA[1] and A. A. LEZHENIN[2]

[1]*Siberian Federal University, Krasnoyarsk, Russia*

E-mail: mikhailuta@gmail.com

[2]*Institute of Computational Mathematics and Mathematical Geophysics, Siberian Branch, Russian Academy of Sciences, Novosibirsk*

E-mail: lezhenin@ommfao.sscc.ru

Abstract

In this work, features of an arrangement and localization of the main sources of soot emissions on the territory of Krasnoyarsk city are considered. It is shown that under the conditions of the complex orography, the circumstances to forming high urban air pollution levels by dust, soot and black carbon are created. Thus, the stationary sources of Krasnoyarsk city throw out in air 129.8 thousand t of the polluting substances a year. Emissions from the largest enterprises amount to 91.9 % of total amount (47.2 % – RUSAL Krasnoyarsk OAO and 44.7 % – Heat Electropower Stations Nos. 1, 2, 3). The proportion of soot in the total amount of emissions amounts to 3 %. But despite this, features of the emission sources arrangement on the territory of the city can form a considerable human health risk level.

Keywords: black carbon, soot, sources of emissions, urban air pollution, air quality

INTRODUCTION

Krasnoyarsk is one of the largest cities of Russia with the population of more than 1 million [1]. There are 649 industrial facilities and almost 6086 stationary sources in the territory of the city. Starting with 1986, the inventory count of emissions in atmospheric air includes more and more the polluting substances.

The emissions inventory into atmospheric air of Krasnoyarsk in 1986 consisted of only 80 polluting substances [2], in 2005 – 203 and in 2012 [3] – already 248. Herewith, maximally permitted concentrations were established for 611 substances [4]. Thus, the implementation of new techniques of performing measurements of the polluting substances in enterprises emissions leads to the information emergence on emissions of "new" substances while all these "new substances" initially were already present in them.

The environmental measures implemented from the federal and regional budgets are aimed at reducing the negative impact on atmospheric air from the industrial sector and in some cases this leads to a decrease in emission volumes (Table 1).

It can be seen that for a number of substances (sulphur dioxide, carbon oxide, suspended matters, and gasoline) a steady decrease in amounts of emissions is observed. But, at the same time in 1986 in inventory count of emissions completely there was no information on amounts of emission of nitrogen dioxide, nitrogen oxide, methane and soot. The observed sharp increase in emissions of kerosene (from 28 to 161 t/y) and soot (from 500 to 3798 t/y) between 2005 and 2012, during reducing number of the entities, is connected not with a production growth in volumes, and with the next revision of techniques of inventory count of emissions.

TABLE 1

Change of emission for the main polluting substances and soot in Krasnoyarsk

Nos.	#	Air pollutant	Emissions volume, t/y		
			1986	2005	2012
1	0301	NO_2	–	19 496	17 209
2	0330	SO_2	54 211	40 795	35 296
3	0337	CO	277 170	101 778	73 738
4	2908	PM	99 356	40 620	22 168
5	0328	Soot	–	579	3798
6	0304	NO	–	2301	2595
7	0410	CH_3	–	–	2002
8	2704	Gasoline	838	219	109
9	2732	Kerosene	84	28	161

This monotonous process of the development of ideas about emissions, in all cities of Russia, and substances coming to the urban atmosphere with emissions, requires development of new approaches to the solution of urban air quality management problems. Measurements of concentration and reasonable evaluation methods of urban air pollutant dispersion estimations shall be the cornerstone of these decisions. Under control shall there are not only the main (the dominating on amounts), but also all substances capable to human health risk. At the same time amounts of emission of these substances can make less than 1 % of the total amount of emissions.

TABLE 2

Amount of the burned coal in a year in Krasnoyarsk

Sources of emissions	Coal, ths. t/y
Heat Electropower Stations Nos. 1, 2, 3	2675
KrasTEK OOO, Local boiler houses Nos. 1–12	135
KrasCOM OOO Local boiler houses Nos. 1–10	40
Regional Thermal Company	70
KraMZEnergo	130
All others	94
Total, ths. t/y	3144

This article describes the distribution of emission amounts of soot on the basic sources of Krasnoyarsk.

RESULTS AND DISCUSSION

The soot proportion in the total amount of emissions for Krasnoyarsk amounts to about 3 %.

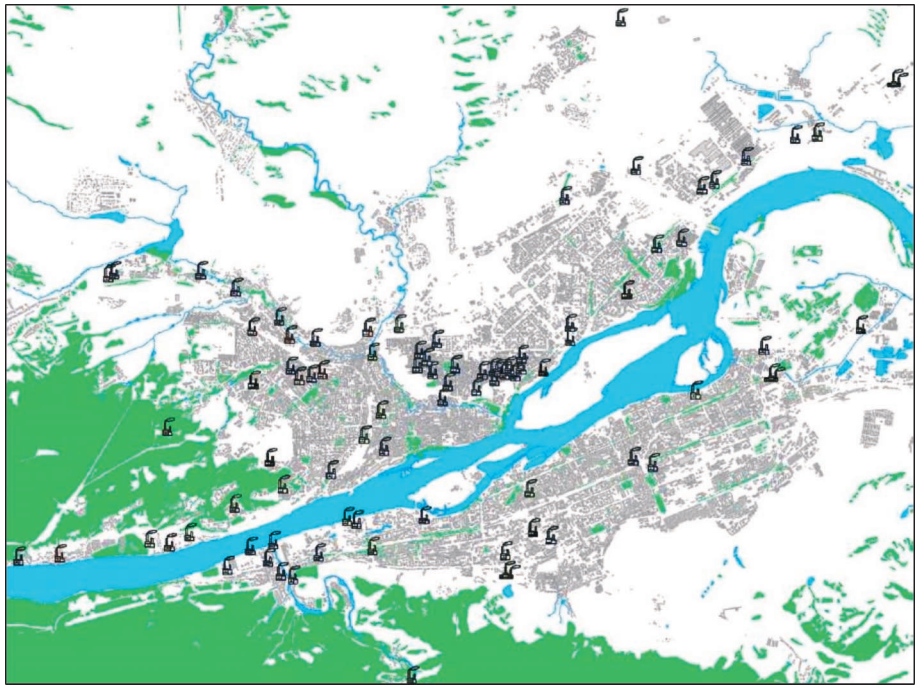

Fig. 1. Sources of emissions of soot in the territory of Krasnoyarsk.

TABLE 3

Sources of soot emissions in the territory of Krasnoyarsk

Sources of emissions	Volume of emissions, soot, t/y	Share from the total amount, %	Stack height, m
RUSAl Krasnoyarsk	1670	39.7	80
Heat Electropower Station No. 1	339.5	11.1	180
The same, No. 2	20.6		180
The same, No. 3	105.4		275
KrasTEK OOO, Local boiler-house No. 1	85.5	6.2	85
The same, No. 2	60.8		80
The same, No. 3	13.7		45
The same, No. 4	10.4		45
The same, No. 5	57.8		50
The same, No. 6	3.4		23
The same, No. 7	3.0		18
The same, No. 10	2.0		31
The same, No. 11	1.2		40
The same, No. 12	24.1		60
Municipal Local boiler-house No. 1	45.5	3.4	45
The same, No. 2	41.3		24
The same, No. 3	22.6		35
The same, No. 4	8.6		24
The same, No. 5	2.5		18
The same, No. 6	2.6		14
The same, No. 7	2.8		23
The same, No. 8	3.2		20
The same, No. 9	4.6		30
The same, No. 10	4.2		18
Local boiler-house Ladoga	4.8		45
Engineering Plant, boiler-house	130.7	3.1	120
Regional Thermal Company	166.4	4.0	120
PharmEnergo	193.3	4.6	70
Railway Car Repair Plant, boiler-house	222.2	5.3	120
City vehicles	410.7	9.8	>1
All others	545.6	13	–
Total volume of emissions, t/y	4209		

Herewith, the sources of emissions cover evenly, the entire territory of the city (Fig. 1).

In the territory of Krasnoyarsk, the entities of metallurgy, three large heat electropower stations and more than seventy small boiler rooms are located.

All together the enterprises of heat power engineering of Krasnoyarsk burn more than 3 million t of coal a year (Table 2).

It can be seen (see Table 2) that the bulk of the burned coal is the share of three largest combined heat and power plants. At the same time the amount of emissions of soot from these combined heat and power plants makes only 11 %.

Consider the distribution of emission amounts of soot on the basic sources of Krasnoyarsk (Table 3).

It can be seen (see Table 3), the amount of emissions of soot in the atmosphere of Krasnoyarsk from stationary sources in a year makes 3798 t and nearly 411 t from motor transport. At the same time, about 40 % of this amount,

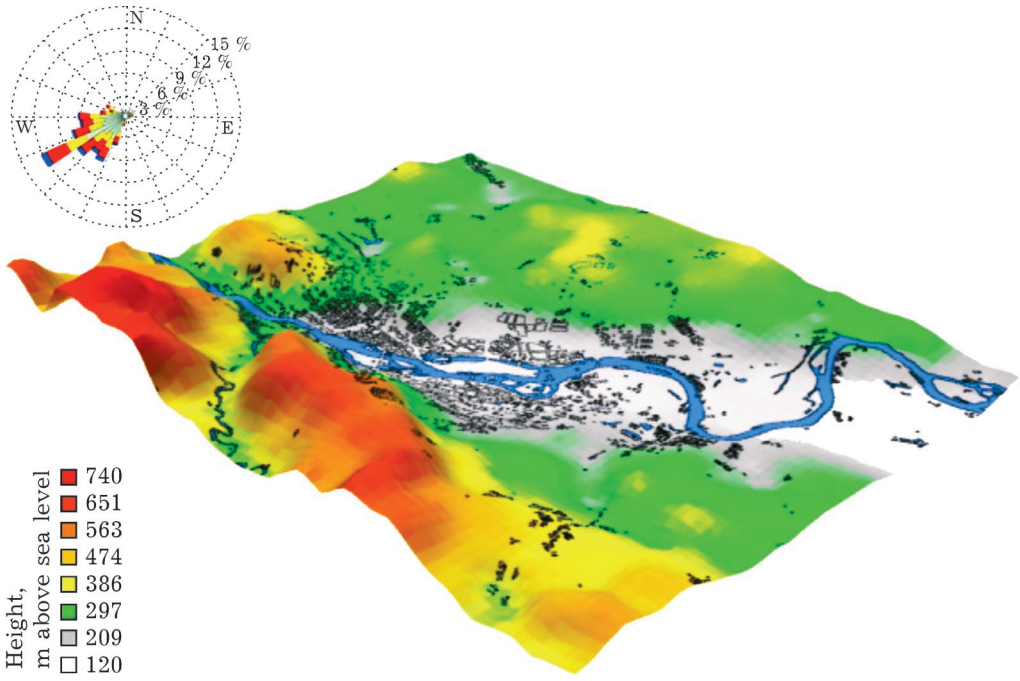

Fig. 2. Relief structure of the Krasnoyarsk Region.

emissions of RUSAL Krasnoyarsk OAO make. About 30 % fall to the share of the entities of power system. At the same time, emissions of soot from only one Heat Electropower Station No. 1 are comparable to amount of emissions from all motor transport in the city (about 400 thousand cars).

Another important feature in many respects determining the nature and degree of the negative impact of soot emissions and black carbon with it in the modern cities is the localization of the enterprises and sources. Thus, considering heights of stacks of the main sources of soot it can be seen that emissions almost evenly fill all high-rise niches, on which the living territories and socially important city facilities are located (Fig. 2).

Krasnoyarsk is located on both banks of the Yenisei River in its mean current on a joint of three geomorphologic areas: 1) valleys of Yenisei, 2) the plateaus adjoining to it and 3) Eastern Sayan foothills.

The valley of the Yenisei occupies the prevailing part of the city. The minimum absolute elevation marks of a bottom of valley are dated for the bed of the river and change from 130–135 m above sea level (see Fig. 2).

The maximum heights with absolute marks 270–300 m (the right bank) and 160–250 m (the left bank) are dated for water separate massifs. In the southeast (the mountain Bald) heights reach 600–700 m above sea level.

Industrial sources of emissions of soot in the territory of Krasnoyarsk are located on the right bank of the Yenisei River on the lower terrace (140 m above sea level), and on left – are located on heights (320, 260, 180, 160 m above sea level). In case of any wind in residential territories considerable concentration of soot and other hazardous substances can form.

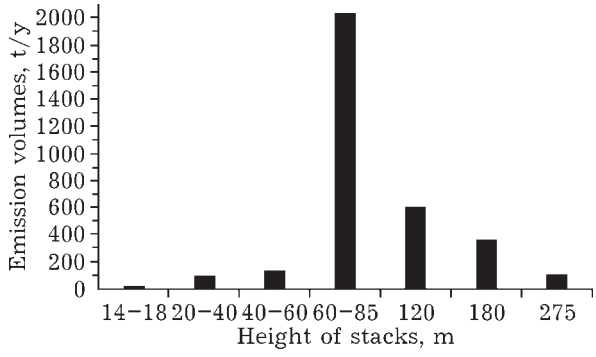

Fig. 3. Distribution of emissions volumes by stacks heights at the Krasnoyarsk city territory.

Fig. 4. View on the main sources of emissions of soot from the residential area in Krasnoyarsk (at the left stacks 80 m high – Krasnoyarsk Aluminium Smelter, in the centre three stacks of the Heat Electropower Station No. 3, 275, 180 and 90 m high).

At the same time, stacks of small boiler rooms have the height from 14 to 40 m, stacks of the sources located in the territories of the entities are 60–85 m, and only large combined heat and power plants have the highest stacks, 120–275 m.

Only 5 stacks in the city have height from 120 to 275 m, and all other stacks are lower than 85 m. At the same time the based mass of soot is thrown out from stacks 60–85 m high (Fig. 3).

It can be seen (see Table 3 and Fig. 3) that more than 2000 t of soot a year are thrown out from stacks less than 100 m high, from the entities which are located at the heights of relief from 140 to 160 m above sea level. Thus the main emission of soot is performed from

Fig. 5. The directions of winds at the meteorological station and in urban areas of Krasnoyarsk (data from 1995–2010 are averaged). At the top left corner is the Krasnoyarsk meteorological station (Index WMO 29570) and the numbered points are the city weather and air pollution monitoring stations in Krasnoyarsk City.

heights of 150–250 m above sea level. It is almost regularly distributed on all relief terraces on which residential districts of the city and socially important objects are located (Fig. 4).

At the same time getting to the lower layer of the urban atmosphere soot, fine particles and other polluting substances are not carried away from the city in the southwest direction as it the wind rose on a meteorological station Krasnoyarsk (the VMO index #29570) assumes, and extends practically on all urban areas and quarters (Fig. 5).

Figure 5 shows that when the meteorological station has prevailing wind from sector 180–270°, some points has only two prevailing (directions with highest probability) sectors for wind streams: 45–55° (northeast direction – opposite to the directions of winds at the meteorological station) and 135–145° (southeast direction). At the same time another point has prevailing winds from the west and southwest for all years, while the winds near Aluminum Plant are mainly from the northwest.

On Krasnoyarsk right bank, in the observation points in the city building development, discrete wind directions located in narrow sectors are also implemented. Thus, for example, in station #8, winds blow all year round from the direction of 225–235° (southwest direction). All the other directions in this point are random events.

Analyses of seasonal and by months of the year the variability of wind directions in the built-up area of Krasnoyarsk for the period from 1995 to 2005 showed that the detected changes (see Fig. 5) were stable and not sensitive to changes in the wind direction at the weather station. Obviously, the observed "distortions" in wind directions are associated with features of the local urban area morphology.

All of this, the arrangement of sources of emissions and urban micrometeorological features caused the homogeneous and increased level of urban air pollution in Krasnoyarsk by particles of dust and soot (Fig. 6).

It can be seen (see Fig. 6) that according to the calculations of dispersion of emissions executed in summary volumes of the maximum allowable emission (MAE) for Krasnoyarsk, the concentration of soot is in all districts of the city is at the level of MPC and this is besides the fact that as shown above the amount of

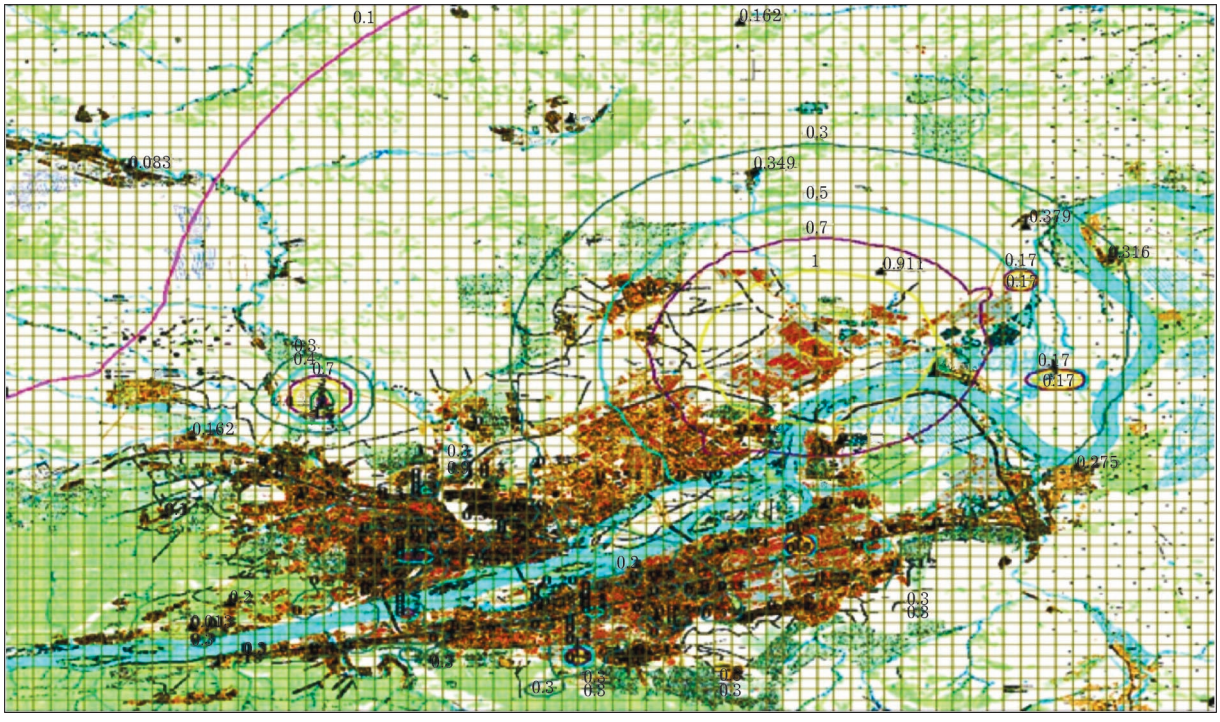

Fig. 6. Estimated isolines of the concentration of soot in the Krasnoyarsk Territory.

emissions of soot makes only about 3 % from the gross amount of emissions.

A similar picture is observed and for many others dangerous and cancerogenic polluting substances.

CONCLUSION

Thus, research of questions of urban air quality management requires special measurements for all pollutants.

Acknowledgement

Work is supported by the Russian Foundation for Basic Research and by the Krasnoyarsk Regional scientific fund No. 15-45-04034 r_sibir_a.

REFERENCES

1 URL: http://ru.wikipedia.org/wiki/Красноярск
2 Emission volume register for Krasnoyarsk, 2012. URL: http://www.krasecology.ru/About/PDV
3 The resolution of the Chief state health officer of the Russian Federation from 05.30.2003 N 114 (an edition from 06.17.2014) "About introduction of GN 2.1.6.1338-03" (together with GN 2.1.6.1338-03. The Maximum Permissible Concentration (MPC) of the polluting substances in atmospheric air of the inhabited places.
4 Complex research of environment and emissions in Krasnoyarsk. Report on research work. No. 01.86.0101492. The subject U.30.08 of the plan of NIR and ROC of Goskomgidromet for 1986–1990 the State Committee USSR on hydrometeorology. Fedorov Institute of Applied Geophysics, Moscow, 1988, 228 p.

УДК 504.064

DOI: 10.15372/KhUR20160403

Черный углерод, сажа и пылевые частицы в атмосфере промышленного города на примере г. Красноярска

С. В. МИХАЙЛЮТА[1], А. А. ЛЕЖЕНИН[2]

[1]Сибирский федеральный университет, Красноярск, Россия

E-mail: mikhailuta@gmail.com

[2]Институт вычислительной математики и математической геофизики СО РАН, Новосибирск, Россия

E-mail: lezhenin@ommfao.sscc.ru

Аннотация

В работе рассмотрены особенности расположения и локализации основных источников эмиссии сажи на территории Красноярска. Показано что в условиях сложной орографии создаются условия к формированию экстремально высоких уровней загрязнения частицами пыли и черным углеродом. Так, выбросы в воздух стационарных источников Красноярска достигают 129.8 тыс. т загрязняющих веществ в год. Выброс от крупнейших предприятий составляет 91.9 % от общего объема (47.2 % – ОАО РУСАЛ Красноярск и 44.7 % – ТЭЦ 1, 2, 3). Доля сажи в общем объеме выбросов достигает примерно 3 %. Но из-за особенностей расположения источники эмиссии черного углерода и сажи на территории города могут представлять значительную угрозу здоровью населения ввиду загрязнения воздуха этими частицами.

Ключевые слова: черный углерод, сажа, источники выбросов, рассеяние, загрязнение атмосферы города, качество воздуха