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Assessment of the influence of geophysical parameters on the value of maximum surface concentrations from emissions of asphalt concrete plants

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Abstract. The influence of geophysical parameters of the coefficient of temperature stratification of the atmosphere and terrain, as well as climatic characteristics on the maximum values of surface concentrations of emissions into the atmosphere is analysed. The results of the presented material make it possible to predict atmospheric pollution by emissions coming from asphalt concrete plants. The paper presents a comparative analysis of the inventory data of the ACP of six cities of the Russian Federation (Perm, Temryuk, Kursk, St. Petersburg, Kaliningrad, and Novgorod); calculations of gross emissions made by specific indicators for all ingredients: dust, carbon monoxide, nitrogen oxides, petroleum hydrocarbons, and sulfur dioxide. The dependence of the maximum surface concentration of a harmful substance on the coefficient of temperature stratification of the atmosphere and the dependence of the maximum surface concentration of a harmful substance on the terrain coefficient are established. There is a significant difference in annual emissions into the atmosphere in different regions with the same productivity and efficiency of treatment systems. The difference in the technogenic load on the environment from the geophysical characteristics of the region is revealed. The significant influence of the geographical location of Russian cities on the norms of maximum permissible emissions and the parameters of their dispersion, in particular, on the maximum surface concentration, is presented.

1 Introduction

Analysis of the location of asphalt concrete plants (ACP) in Russia shows that they are located in a wide range of climatic and geophysical factors and affect the production facilities of the agro-industrial complex. Despite the extreme urgency of this problem, it has not been sufficiently investigated, although there is a lot of information in the foreign

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literature about the impact of ACP on the atmosphere, depending on their geographical location.

2 Mass emissions of ACP located in the European part of Russia

We carried out the analysis of the inventory data of ACP located in the European part of Russia. This analysis shows that the mass (annual) emissions of the normalised ingredients are the values presented in Table 1.

Table 1. Mass emissions from ACP mixers, t/year.

№	Ingredients	Perm	Temryuk	Kursk	Saint-Petersburg	Kaliningrad	Novgorod
		D-508-2A			D-597		
1	Dust	2.4	15.1	8.6	40.8	17.2	28.5
2	CO	2.43	1.467	5.03	10.73	5.2	5.869
3	NO	0.1	0.782	-	0.79	5.03	0.2
4	SO_2	0.053	1.3445	0.31	0.05	2.51	-
5	Hydrocarbons	8.51	7.34	3.078	33.97	40.22	18.1

It has also been established that dust and hydrocarbons are dominant in the emissions of mixers D-508-2A and D-597 where the latter has significantly lower cleaning efficiency.

3 Geographical features of the location of the ACP on the territory of Russia

According to the inventory of the ACP of six cities of the Russian Federation (Perm, Temryuk, Kursk, Saint-Petersburg, Kaliningrad, Novgorod) instrumental measurements have established specific indicators of emissions into the atmosphere of dust, carbon monoxide, nitrogen oxides, petroleum hydrocarbons and sulfur dioxide [1-4].

Perm is located at latitude 58°00' N, longitude 56°19' E. The relief of the Perm region was formed under the influence of mountain-forming processes in the Ural Mountains, as well as marine and continental sedimentation on an ancient crystalline platform foundation and is very diverse. The western part (approximately 80% of the territory) is located on the northeastern edge of the East European Platform and in the regional sag before the Ural mountains; flat and low-lying relief prevails here. The eastern part is mountainous, including the western slopes of the southern part of the Northern and northern parts of the Middle Urals [5-8].

Perm's climate is continental. The proximity of the Kama reservoir causes increased humidity.

Novgorod is located at latitude 58°25' N and longitude 33°54' E.

Novgorod region is located in the north-west of the Russian (East European) plain, within the lowland near Ilmen and the northern spurs of the Valdai Hills, in the forest zone.

The surface of the Russian plain within the region has a wavy character. The lowest places fall on the lowland near Ilmen (from 180 to 50 m above sea level), the highest, on the Valdai Hills (about 300 m above sea level).

The climate of the Novgorod region is temperate continental, close to the sea.

Saint Petersburg is located at latitude 59°24' N and longitude 30°49' E. The city is located in the north-west of the Russian Federation, within the the lowland near Neva, on the coast of the Neva Bay of the Gulf of Finland adjacent to the mouth of the Neva River and on numerous islands of the Neva Delta.

The maximum relief heights in the southwest of the city are 176 m, in the north in Pargolov about 60 m. There are no steep ascents and descents in the city, but the presence of different levels is noticeable. St. Petersburg is located on various terraces, rock-moraine hills and ledges of clay up to 50 m high, the central part of the city is in the riverine–delta zone with heights up to 6 m.

The humid maritime climate of St. Petersburg with warm summers and unusually temperate winters for such a geographical latitude is explained by the influence of the Gulf Stream.

Kursk is located at latitude 51°46' N, longitude 36°10' E, altitude above sea level – 247 m.

The relief of the Kursk region is valley-ravine-girder. The location of the region is favourable. It lies on the south-western slopes of the Central Russian Upland. The city is located in a forest-steppe zone.

The climate of the city is moderately continental.

Temryuk is located at latitude 45°16' N and longitude 37°23' E. It is located 130 km west of Krasnodar, on the right bank of the Kuban River, at its confluence with the Temryuk Bay. The Taman Peninsula, on which the Temryuk district is located, is washed by two seas — the Black and the Azov.

In the west of the peninsula — from Cape Tuzla to Taman — the shores of the Black Sea are high (from 15 to 30 meters) and steep. To the east, they pass into the sandbanks of the old (Black Sea) and modern (Azov) mouths of the Kuban.

The climate of the Temryuk district is temperate, transitional from marine to continental.

Kaliningrad is located at latitude 54°43' N and longitude 20°30' E. Kaliningrad region is located on the southeastern coast of the Baltic Sea, is the westernmost territory of Russia.

The natural morphological appearance of the region was formed as a result of the activity of the last (Valdai) glaciation and reflects the regular alternation of vast flat and low-lying spaces with separate hilly-ridge elevations. The most highly elevated is the southern part of the region.

In the south-west of the region is the Warmian upland, in the south-east, Vishtynetskaya upland, which are separated by the valley of the Lava River. The highest point of the Warmian upland reaches 101 m and Vishtynetskaya upland, up to 230 m.

The named elevations are joined from the north by the spaces of the Pregolskaya lowland. Its height above sea level is from 13 to 25-30 m, which contributes to the formation of rather large wetlands on it.

The north-eastern part of the region is occupied by the Sheshup lake-glacial plain, on which separate hills rise and tributaries of the Kacha River originate.

From the west, the plain is bordered by the Kurch-Sambi hilly-moraine ridge. It stretches in a huge arc almost through the entire region along the valleys of the Kacha and Pregoli.

East of the Kaliningrad - Zelenogradsk line is the Polessky lake-glacial lowland, whose height above sea level is small, which also causes its waterlogging. Some areas of the lowlands are below the level of the Baltic Sea up to 1.2 meters.

The climate of the region is transitional from maritime to temperate continental.

4 Dependence of ACP emissions on the geophysical characteristics of the region

A schematic map of the isolines of air temperatures and information in the cold period of the year in the locations of the ACP indicate that the duration of trouble-free operation of the ACP equipment during the year may be limited by negative air temperatures (t_a). At the same time, the number of days from $t_a \geq 0^0C$ ranges from 365 days (Sochi) to 98 days (Dixon urban settlement). With an eight-hour daily schedule of ACP mixers, the working time of ACP for the year will be 2920 hours and 784 hours, respectively [9-12].

Calculations of gross emissions made by specific indicators for all ingredients are presented in the table in the form of minimum and maximum values for Sochi (Table 2) and Dixon (Table 3) for mixers D-597 (single-stage dry cleaning) and D-508-2A (two-stage dry and wet cleaning).

Table 2. ACP mixers emissions in the City of Sochi.

Sochi – D-597					Sochi – D-508-2A				
CO, tons per year	NO_x tons per year	Petroleum hydrocarbons, tons per year	SO_2, tons per year	Dust, tons per year	CO, tons per year	NO_x tons per year	Petroleum hydrocarbons, tons per year	SO_2, tons per year	Dust, tons per year
5.68-32.6	0.37-6.94	5.68-130.56	3.68-5.11	40.16-590.15	0.94-29.65	0.37-6.73	0.53-98.82	0.94	10.6-460.7

Table 3. ACP mixers emissions in the City of Dixon.

Dixon – D-597					Dixon – D-508-2A				
CO, tons per year	NO_x tons per year	Petroleum hydrocarbons, tons per year	SO_2, tons per year	Dust, tons per year	CO, tons per year	NO_x tons per year	Petroleum hydrocarbons, tons per year	SO_2, tons per year	Dust, tons per year
1.53-8.77	0.09-1.87	0.15-98.82	0.99-1.38	10.79-158.45	0.26-7.96	0.09-1.81	1.53-35.06	0.26	2.86-123.7

In this regard, it should be noted that with the same productivity and the same efficiency of their purification, annual emissions may differ significantly, which determines the difference in the anthropogenic load on the environment. The analysis of the data obtained shows an almost fourfold excess of gross emissions in Sochi compared to Dixon.

Geographic location of the cities of Russia significantly influences the maximum permissible emissions (MPE) and dispersion parameters, in particular the maximum near-ground concentration (C_m) and distance from the source to it (x_m) [13-15].

These parameters of MPE, C_m, and x_m include geophysical characteristics of the region with dependencies (1) and (2):

$$C_m = \frac{\mathrm{AMFmn}\eta}{H^2\sqrt[3]{V_1 \Delta T}}, \mathrm{mg}/m^3, \tag{1}$$

$$\mathrm{MPE} = \frac{(\mathrm{MPC} - C_f)\mathrm{H}^2\sqrt[3]{\Delta \mathrm{TV}_1}}{\mathrm{AFmn}\eta}, \mathrm{g/s}, \tag{2}$$

A – coefficient depending on the temperature stratification of the atmosphere; *m*,

η – coefficients taking into account the conditions of the gas-air mixture exit from the mouth of the emission source;

η – a dimensionless coefficient that takes into account the influence of terrain;

H – height of the emission source above ground level, m;

M – mass of harmful substance released into the atmosphere, g/s;

F – a dimensionless coefficient that takes into account the rate of deposition of harmful substances in the atmosphere; depends on the degree of purification: if $y \geq 90$ % F=1; $75<y<90$% F =2,5; $y \leq 75$%; F=3; F=1 for gaseous substances and fine dust;

V_1 – consumption of the gas-air mixture;

$T_{a.t.h.m.}$ – average temperature of the hottest month ($\Delta T = T_g - T_{a.t.h.m.}$);

ΔT – the difference between the temperature of the emitted gas-air mixture and the ambient air temperature, ^{0}C;

T_g – the temperature of the gas at the outlet of the source.

Dependence $C_m = f(A)$ is shown on the Figure 1 which shows that the maximum near-ground concentration , in case of other equal parameters of the formula (1), increases by 80% with A increasing from 140 (Moscow) till 250 (Chita).

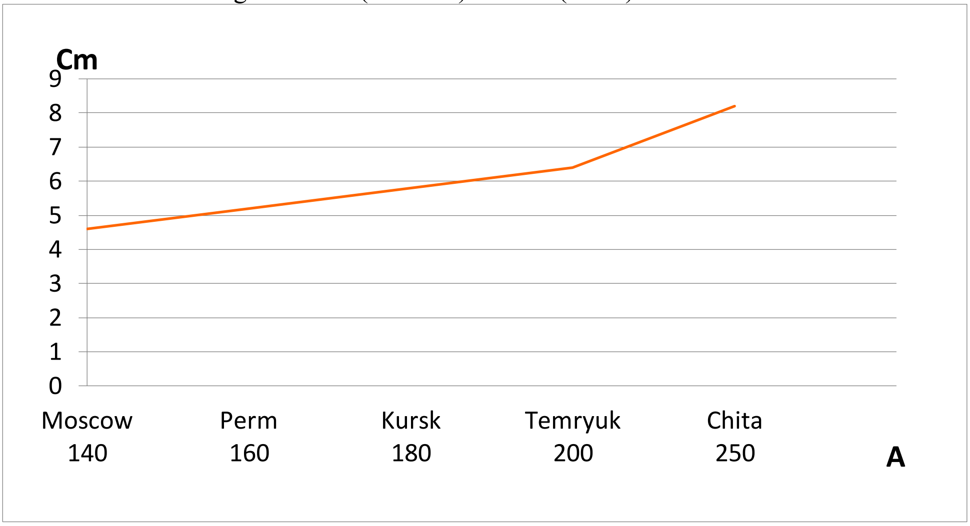

Fig. 1. Dependence of the maximum near-ground concentration of a harmful substance on the coefficient of temperature stratification of the atmosphere.

Dependence Cm=f(η) is shown on the Figure 1. It specifies that the maximum surface concentration increases by 72% when the ACP is functioning on a hill compared to the lowlands.

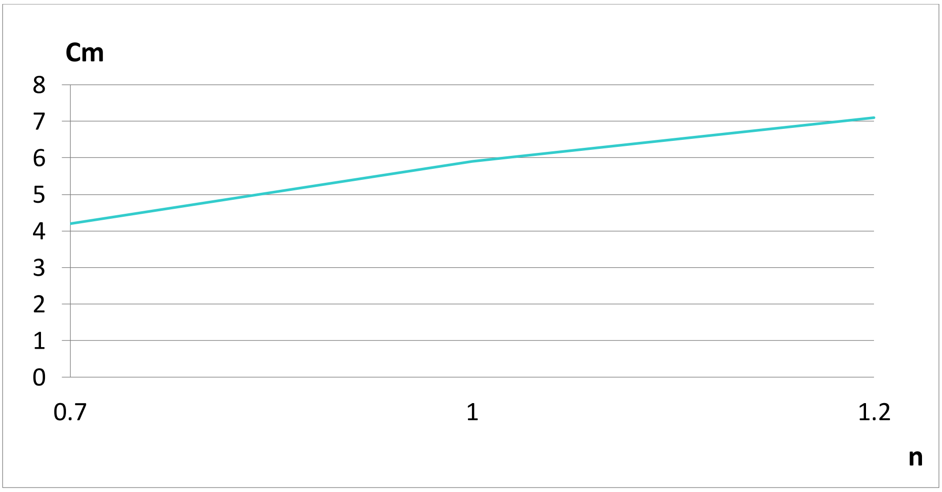

Fig. 2. Dependence of the maximum surface concentration of a harmful substance on the terrain coefficient.

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5 Conclusion

The results of the analysis of the material allow specifying the influence of geophysical parameters on the value of the maximum near-ground concentrations from emissions of asphalt concrete plants, which makes it possible to reduce the complexity of the development of MPE standards due to their forecast estimates.

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