

Estimation of the permissible level of motor transport traffic' intensity in the urban streets as regards the pollutants' emissions

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Abstract. Calculations of emissions and dispersion of pollutants in the air of streets were carried out and concentrations of pollutants in the air of streets created from emissions of motor transport were determined. Based on the calculations it was proposed that for the city of Almaty the permissible level of the motor transport traffic' intensity is about 300,0-350,0 vehicles/hour. Under such traffic intensity content of pollutants in the atmospheric air will not exceed the sanitary standards.

Keywords: motor transport, atmospheric air, quality, pollution, permissible traffic intensity, calculation.

1. Introduction

Motor transport is one of the main sources of the air pollution in the cities resulting in the serious environmental problems and creating risks for the population health. Under rapid growth of urban population and number of vehicles, especially in the developing countries, the motor transport' impact on the atmospheric air quality becomes more and more pressing. According to the data of the World Health Organization, more than 90 % of urban population breathes the air, which contains the pollutants exceeding the permissible standards, resulting in increase of morbidity and mortality from respiratory and cardiovascular diseases [1]. This fact points out on the need to conduct the studies aimed on determination of permissible number of motor transport in the urban streets.

Growth of the vehicles' number is observed in the majority of countries. This is directly connected to the increase of emissions of such pollutants as: nitrogen oxides (NO_x), carbon (CO), solid particles (PM) and volatile organic compounds (VOC). Situation with the air pollution by motor transport varies in different countries of the World. In the developed countries, such as: the USA and European Union countries, the measures to decrease the emissions are taken, including the implementation of the environmentally clean technologies and public transport' development [2, 3].

Realization of studies on determination of permissible number of motor transport in the urban streets is the important step towards the improvement of the atmospheric air quality. Such studies help to reveal the optimum parameters of the transport flow, which minimize the pollutants emissions and support the development of the effective transport management strategies.

Review and analysis of the conducted studies on the motor transport traffic and air pollution in the cities' streets shows that the problem of the atmospheric air pollution is one of the most

urgent problems in the modern megapolises.

During the last years a lot of studies devoted to the motor transport influence on the air pollution were conducted. Influence of the motor transport traffic on the urban air quality is given in Articles [2, 3-7]. Analysis of the air pollution by motor transport emissions in the United States shows the strong correlation between the motor transport traffic' intensity and NO_x emissions, with higher levels of NO_2 concentrated along the main roads. The study emphasizes the necessity to continue the efforts on reduction of the motor transport emissions [2].

In Article of Qi Wang et al. the qualitative evaluation of the road traffic influence, including the traffic jams, on the urban air quality is given. This study provides the support and basis for the traffic' planning and management [4].

The air pollution related to the transport traffic is especially significant in the urban districts and particularly - in the city cores, where the most intensive transport traffic and traffic jams are observed. This is proved based on the long-term evaluation of the influence of the motor transport emissions on nitrogen dioxide (NO_2) content in the atmospheric air [5]. Transport traffic is one of the main sources of the air pollution in the European cities [6]. This Article considers, which characteristics of the urban environment may influence the air pollution as regards the transport. Rapid growth of the vehicles number in China resulted in accumulation of such pollutants as: CO , NO_x and SO_2 in the atmosphere, especially in the urban areas. So, based on example of the city of Anqing (China), content of vehicles with different emission standards was analyzed. This study shows the interconnection between the emissions, traffic amounts and types of vehicles producing such emissions [8].

V. Shepelev et al. proposed a new approach to evaluation of influence of changes in the transport flow on the pollutants emissions and carrying capacity of the signal-controlled road crossings (junctions) [9]. The basis for management of uncertainty of urban traffic' emissions related to the vehicles' content from the point of view of the spatial-temporal sampling' coverage is proposed in Article [10]. Results given in this Article may decrease the uncertainty in the emissions calculations resulted from the insufficient sampling coverage and may support more accurate drafting of policy on reduction of transport emissions. Rapid growth of vehicles number in urban areas results in serious consequences – air pollution with gases. The combined structure for forecasting of future evolution of transport emissions based on GPS trajectories of taxi with multichannel spatial-temporal network, and model of transport emissions' simulating is proposed (MOVES) [11].

Pollution of the atmospheric air with harmful substances is the most important problem for the city of Almaty, Kazakhstan. The city' specific meteorological conditions, low level of air exchange contributes to the pollutants' accumulations in the atmosphere and smog creation in the city. The motor transport emissions are the main source of the atmospheric air pollution. Their share amounts to more than 60 % of total gross emissions in the city. The most polluted sites of the city territory are mainly confined to the areas with the intensive motor transport traffic [12].

The city is loaded with motor transport. According to the reported data there are more than 600 th. vehicles. Besides, about 200 th. vehicles enter the city every day coming from the neighboring districts. The intensity of transport flow at the main arterial roads of the city is 6000 vehicles/hour and even more.

Results of monitoring of the atmospheric air quality at the ecological stations showed the connection between growth of the pollutants content within 24-hours and growth of the vehicles' number on the main road. As the motor transport traffic intensity increases in the streets during the day time, concentrations of the pollutants in the air (PM_{10} , $\text{PM}_{2.5}$, NO_2 , CO) also increase and amount to the values exceeding the maximum permissible concentrations (MPC) [12-13].

In order not to allow formation of levels of the atmospheric air pollution, which exceed the maximum permissible concentrations (MPC), it is necessary to carry out work on reduction on the emissions' volume by means of restricting the motor transport traffic. For this purpose, it is required to calculate maximum motor transport traffic' intensity for the site of road network, at which the dispersion of pollutants emitted by motor transport will not result in formation of the

increased levels of the atmospheric air pollution at the areas adjacent to the main road.

The present conducted Study is aimed on determination of permissible intensity of the motor transport traffic in the urban streets, taking into account the amounts of the pollutants' emissions. The existing studies were analyzed, influence of different factors on level of the atmospheric air pollution was estimated. Recommendations on transport flows' optimization were developed.

It is anticipated that the Study results will support the development of the most effective strategies on transport traffic' management, which, in their turn, will result in improvement of the atmospheric air quality in the cities.

Originality and novelty of the present Study is in determination of qualitative connection between the pollutants' concentrations in the outdoor air and transport traffic intensity.

The actual significance of the conducted Study lies in its practical orientation and possibility to use the received data for formation of the environmental policy at the municipal administrations' level.

2. Methods

The motor transport emissions into the atmosphere of the city' streets were calculated based on the international methods of inventory of harmful substances emissions EMEP/ EEA (CORINAIR). Computer software COPERT 5.7 was used to calculate the emissions, taking into account the structure and status of the motor transport fleet in Almaty. Emissions of the following pollutants were calculated: carbon oxide CO, nitrogen oxides NO_x, hydrocarbons CH, solid particles PM₁₀, PM_{2,5}, sulphur oxides SO₂, etc. [14].

Flow intensity (number) of motor transport traffic in the city' streets was determined according to "Methods of determination of the pollutants emissions into the atmospheric air from mobile sources for realization of summary calculations of the atmospheric air pollution" [15].

The pollutants concentrations in the atmospheric air, created by the motor transport emissions were determined according to the "Methods of calculation of the harmful substances (pollutants) dispersion in the atmospheric air" [16]. Computer software ERA-UPR3A "Calculation of the atmosphere pollution" was used to calculate the pollutants' dispersion in the streets' air [17].

3. The study results

The procedure of the method on determination of permissible number of the motor transport traffic in the urban streets as regards the pollutants emissions is as follows:

- Determination of the pollutants' specific emissions by vehicles taking into account the structure, type, content of the city' motor transport fleet.
- Determination of the motor transport traffic' intensity in the main streets of the city.
- Calculation of the capacity (amount) of the pollutants' emissions at the street' sites.
- Calculations of the pollutants' dispersion in the atmospheric air, determination of the pollutants' concentrations created by the motor transport emissions.
- Comparison of the pollutants' concentrations created by the motor transport emissions with sanitary standards (maximum permissible concentration MPC).
- Determination of the permissible level of the motor transport traffic' intensity in the urban streets as regards the pollutants' emissions, which provide the sanitary standards of the atmospheric air quality.

As of the year 2023 in Almaty 573813 vehicles were registered. Volume of pollutants emitted by the motor transport amounted to 65964,7 tons.

Based on the data of annual emissions by each type of vehicles, by number and annual mileage, the specific emissions of each type of the vehicles (g/km) in Almaty streets were determined. Results of calculations of the specific emissions are given in Table 1.

The parts of the main roads with the intensive motor transport traffic, located in the central part of the city of Almaty, were selected in order to calculate the pollutants dispersion. Calculation

of capacity of the pollutants' emissions (emission in g/sec) at the selected part of the main road is done by number of vehicles passing the part during the time unit (hour), by specific emissions of the separate types of motor cars and by length of the street part, for each group of vehicles and each substance.

Table 1. Specific emissions of the vehicles in the streets of Almaty, g/km

No.	Substances, g/km	Vehicle type							Average by all types of vehicles
		Passenger	Buses			Trucks			
			Small, up to 3,5 t	Large diesel	All buses	Commercial up to 3,5 tons	Large diesel	All trucks	
1	All substances	6.23	12.71	10.08	10.90	26.34	11.58	19.1	7.22
1	Carbon oxide, CO	4.74	9.82	2.08	4.51	20.60	2.07	11.50	5.10
2	Nitrogen oxide, NO	0.28	0.80	4.40	3.60	1.20	6.61	3.60	0.70
3	Nitrogen dioxide, NO ₂	0.08	0.15	1.1	0.48	0.30	1.10	0.95	0.10
4	Nitrogen oxides, NO _x	0.36	0.95	5.50	4.08	1.50	7.71	4.55	0.80
5	Sulphur oxide, SO ₂	0.01	0.02	0.08	0.06	0.02	0.08	0.05	0.02
6	Solid particles, PM ₁₀	0.03	0.06	0.36	0.26	0.04	0.32	0.18	0.05
7	Solid particles, PM _{2,5}	0.02	0.04	0.30	0.22	0.03	0.27	0.14	0.04
8	Hydrocarbons, CH	0.53	0.90	0.88	0.89	2.08	0.51	1.31	0.59

As the calculations showed, the emissions' volume (emission in g/sec), for example, carbon oxide CO, under intensity of motor transport traffic of 2058 vehicles/hour decreases by 51,8 % in comparison with traffic intensity of 5010 vehicles/hour, and volume of emissions of solid particles PM₁₀ decreases by 52,2 %. Volumes of emissions of other pollutants also decrease. Results of calculations of the pollutants' dispersion in Almaty streets are given in Table 2.

Under conditions of the city of Almaty and under traffic intensity at the main roads of 3018 vehicles/hour, 5010 vehicles/hour and more, concentrations of the pollutants in the air (solid particles PM₁₀ and PM_{2,5}, nitrogen oxides NO and NO₂) exceed their average daily maximum permissible standards. Under motor transport traffic intensity of 2058 vehicles/hour, 972 vehicles/hour and less, concentrations of the pollutants in the air do not exceed their average daily maximum permissible standards (Table 2). Further calculations showed that under normal meteorological conditions in Almaty the permissible intensity of motor transport traffic on the main roads is about 300,0-350,0 vehicles/hour. Under such intensity of motor transport traffic, the pollutants' emissions will not result in formation of levels of the pollutants' content in the atmospheric air, which exceed the sanitary standards established in the Republic of Kazakhstan.

It is necessary to point out that final calculated concentrations of the pollutants in the atmospheric air in the areas of main roads also depend on the input background levels of the pollutants' content in the atmospheric air in the given district of the city. They also depend on meteorological conditions, velocity of wind, which determines the substances' turbulent distribution in the air, character of housing. It is necessary to take into consideration all these factors determining the number of motor vehicles by the pollutants' emissions at the exact street of the city.

The methods on determination of permissible intensity of motor transport traffic by the pollutants emissions in the urban streets is given in the present Study. Further investigations are required to develop the proposed method for the purpose of its practical use in the cities.

Table 2. Calculation of the pollutants' dispersion in Almaty streets

No.	Street name and part	Length of the street part, km	Number, car/h	Substance	Specific emission, g/km	Emission, g/sec	Concentration in the air, mg/m ³	Average daily MPC, mg/m ³	MPC share, average daily
1	Raimbek av., from Abylai-khan av. to Panfilov str.	0,250	5010	CO	5.10	1.8180	0.1322	3.000	0.044
				NO	0.70	0.2030	0.2374	0.060	3.957
				NO ₂	0.10	0.0523	0.1325	0.040	3.313
				PM10	0.05	0.0180	0.1986	0.060	3.310
				PM2,5	0.04	0.0114	0.1385	0.035	3.957
				SO ₂	0.02	0.0049	0/0049	0.050	0.098
2	Tole-bi str., from Seifullin av. to Nauryzbai-batyr str.	0,300	3018	CO	5.10	1.2827	0.1069	3.000	0.036
				NO	0.70	0.1761	0.1377	0.060	2.295
				NO ₂	0.10	0.0252	0.0835	0.040	2.088
				PM10	0.05	0.0126	0.1169	0.060	1.948
				PM2,5	0.04	0.0101	0.0432	0.035	1.234
				SO ₂	0.02	0.0051	0.0024	0.050	0.048
3	Gogol str., from Baitursynov str. to Masanchi str.	0,300	2058	CO	5.10	0.8747	0.0123	3.000	0.004
				NO	0.70	0.1201	0.0719	0.060	1.198
				NO ₂	0.10	0.0172	0.0213	0.040	0.533
				PM10	0.05	0.0086	0.0317	0.060	0.528
				PM2,5	0.04	0.0069	0.0178	0.035	0.509
				SO ₂	0.02	0.0035	0.0013	0.050	0.026
4	Kabanbai-batyr str., from Abylai-khan av. to Nauryzbai-batyr str.	0,400	972	CO	5.10	0.5508	0.0049	3.000	0.002
				NO	0.70	0.0756	0.0164	0.060	0.273
				NO ₂	0.10	0.0108	0.0046	0.040	0.115
				PM10	0.05	0.0054	0.0264	0.060	0.440
				PM2,5	0.04	0.0044	0.0044	0.035	0.126
				SO ₂	0.02	0.0022	0.0004	0.050	0.008

4. Conclusions

- 1) Motor transport emissions in the city of Almaty have the priority impact on the atmospheric air quality in the areas of the main roads and streets with the intensive road traffic. Content of fine particles PM10 and PM2,5 as well as NO₂ and CO in the atmospheric air increases as the road traffic intensity grows.
- 2) The qualitative characteristics of connection between the road traffic intensity and pollutants' concentration in the atmospheric air in the areas of the main roads was established.
- 3) The permissible road traffic intensity in the urban streets of Almaty under normal meteorological conditions is about 300,0-350,0 vehicles/hour. Under such road traffic intensity, the pollutants emissions will not result in the formation of the pollutants' content in the atmospheric air, which exceeds the sanitary standards established in the Republic of Kazakhstan.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of interest

The authors declare that they have no conflict of interest.

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