Study of the degree of atmospheric air pollution on a segment of the city highway

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Abstract. The article presents the results of experimental and theoretical studies, as a result of which the impact of traffic organization on the level of air pollution from traffic flows was assessed. The studies were carried out on several sections of one segment of the city highway. The assessment of the state of atmospheric air pollution on a highway with heavy traffic (Mira Avenue, Omsk) was carried out on the basis of determining the content of carbon monoxide (CO) in the air, as one of the main components of the exhaust gases of the traffic flow. Calculations are graphically presented that confirm the unevenness of the amount of pollutant emissions by one passenger car that moves along a segment of a city highway, taking into account several options for traffic regime. Modes of movement are due to the organization of road traffic.

1. Introduction
Along with an increase in the level of motorization, the degree of negative impact of the motor transport complex on the environment in the form of various types of pollution increases [1]. For large cities, to a greater extent, this is manifested in atmospheric air pollution by exhaust gases from traffic flows [2,3,4]. Among the factors affecting the level of air pollution in the vicinity of the highway from the traffic flow, the quality of the organization of traffic at intersections and on segments of city highways plays an important role [3,4,5,6]. Previously, the authors presented theoretical calculations of the unevenness of the amount of pollutant emissions by one passenger car moving along a conventional segment of a city highway. The length of the section was 1 km. As a result, a relationship was obtained between the amount of pollutant emissions and traffic modes, which is due to the level of traffic organization [7]. In this work, to assess the level of atmospheric air pollution, a series of field experiments were carried out, the results of which are contained in this article.

2. Theory
Investigation of the level of air pollution of urban highways by exhaust gases of motor transport can be carried out both by experimental and calculation methods [2,3,8,9]. It is legitimate to conduct field surveys to determine the level of air pollution caused by emissions from road transport in accordance with the requirements of regulatory documents in force in the country [9, 10].

The assessment of the state of atmospheric air pollution on the highway with heavy traffic (Mira Avenue, Omsk) was carried out on the basis of determining the content of carbon monoxide (CO) in the air. Carbon monoxide is one of the main components of exhaust gases from traffic flows [10, 11].
The studies were carried out in October 2019 during the working day of the week (09.10.2019, Wednesday) from 09:00 to 18:00 at three points of one segment of Mira Avenue (figure 1). At each of these points, four series of measurements were carried out [12].

Based on the purpose of the study, the observation points were selected taking into account the following conditions:
1) the presence of general aeration characteristics of the territory:
   - location in plan in relation to the "rose wind" (from southeast to northwest);
   - the width of the carriageway (21.0 m), the number of lanes (3 in each direction);
   - type and number of storeys of buildings (linear 5 floors, at a distance of 20 m);
   - lack of green spaces;
   - lack of longitudinal slopes and curves in the plan;
2) absence of large-capacity off-street parking lots near stationary sources of atmospheric pollution;
3) lack of uniformity of vehicles (on the investigated stretch of Prospect Mira, the movement of goods vehicles weighing more than 3.5 tons is prohibited);
4) the presence of differences in the prevailing modes of movement on the sections, due to the existing organization of traffic [6].

Organization of traffic on the studied sections of the Mira Avenue segment:
- section No. 1 (public transport stop "SibADI"): maximum permitted speed - 60 km/h (according to the traffic rules of the Russian Federation); parking on the edge of the carriageway is prohibited by sign 3.27 "Stopping prohibited"; the presence of an underground pedestrian crossing and limiting railings; horizontal road markings are present; (1.3, 1.5 according to GOST R 51256-2018 [13]; in the immediate vicinity there is an unregulated crossroads with Tvardovskogo Street, where it is allowed to turn left and turn from the oncoming segment of Mira Avenue; automatic photo - video recording of traffic violations is absent; present driving modes - constant speed, acceleration.
- Section number 2 (public transport stop "Medical Academy"): maximum speed - 60 km/h with the presence of photo and video recording of violations of the speed limit (sign 3.24 "Maximum speed (60 km/h)" with plate 8.23 "Photo - video fixation"); the presence of a public transport stop and an adjustable pedestrian crossing with a pedestrian signal call board, in the direction of travel; horizontal road markings are present (1.3, 1.6); there are no intersections; prevailing driving modes - constant speed, deceleration, idle;
- Section 3 (public transport stop "Technical University"): maximum speed - 60 km/h according to traffic rules; parking on the edge of the carriageway is prohibited by sign 3.27 with plate 8.24 "Tow truck is working"; the presence of the and an adjustable pedestrian crossing with a in front of the observation point in the direction of travel; the presence of an adjustable pedestrian crossing with a pedestrian signal call button and a public transport stop in front of the observation point in the direction of travel; horizontal
road markings are present (1.3, 1.5); there are no intersections; the prevailing modes of movement are constant speed, acceleration.

During the period of the experiment, there were no road accidents, repairs and other emergency situations affecting the traffic regimes on the studied street segment.

The air temperature on the day of the experiment was 22°C. Other meteorological conditions present on the day of observation for each measurement period are presented in table 1.

**Table 1.** Main meteorological parameters during observations.

| Number | Time period | Wind speed | Wind direction | Humidity | Precipitation | Cloudy |
|-------|-------------|------------|----------------|----------|---------------|--------|
| 1     | 09:00 – 10:00 | 6 km/h     | Southeastern   | 58%      | No            | 9%     |
| 2     | 12:00 – 13:00 | 9 km/h     | Southeastern   | 41%      | No            | 10%    |
| 3     | 15:00 – 16:00 | 17 km/h    | South, Southeastern | 29% | No            | 48%    |
| 4     | 17:00 – 18:00 | 17 km/h    | South, Southeastern | 32% | No            | 86%    |

Field surveys of the level of atmospheric air pollution were carried out using a Geolan-1P gas analyzer. The device is designed for continuous direct measurement of the concentrations of harmful and pollutants in the air [14]. The device was placed at each observation post at a height of 1.5 m from the ground at the edge of the carriageway (figure 2, a). The device carried out continuous measurements of the surface concentration of carbon monoxide in the atmosphere for 20 minutes.

Simultaneously with taking air samples using a digital video camera, the number of passing vehicles was recorded (figure 2, b), which are divided into five main categories (in accordance with GOST R 56162-2014) [15].

![Figure 2](image1.jpg)  
**Figure 2.** Stages of experimental research: a - installation of experimental equipment in accordance with the standard; b - video recording of current values of carbon monoxide concentration and traffic flow parameters.
In addition to the above parameters, during the experiment, the following were recorded: the number of uniformly moving vehicles; the number of vehicles in acceleration mode; the number of vehicles slowing down. For vehicles that move evenly, their speed was determined. Determination of the speed of movement on the studied sections of the segment was carried out by measuring the time spent by a car to travel the distance of the base section of the road with a sample of 100 cars [16, 17].

3. Research results

Cameral processing of the obtained experimental data was carried out in two stages. One stage is associated with the processing of traffic flow parameters, the other with the processing of air pollution indicators.

At the first stage, the traffic flow intensity was calculated and identified by its composition. The processing of the measurement results was carried out on the basis of the obtained data from the video camera. The selected time interval was 20 minutes. Figure 3 graphically reflects the dependence of the traffic intensity on the time of day at the points of the investigated segment of the Avenue Mira.

![Figure 3](image.png)

**Figure 3.** The intensity of movement at the points of the studied segment Mira Avenue for a 20-minute measurement period: 1 - opposite public transport stop "SibADI"; 2 - before the public transport stop "Medical Academy"; 3 - for the public transport stop "Technical University".

During the first stage of research, it was found that the composition of the traffic flow in the studied sections of the Mira Avenue segment is practically the same:
- public transport stop "SibADI": cars - 83%; buses - 3%; minibuses and trucks up to 3.5 tons - 14%;
- public transport stop "Medical Academy": cars - 82%; buses - 4%; minibuses and trucks up to 3.5 tons - 14%;
- public transport stop "Technical University": cars - 84%; buses - 4%; minibuses and trucks up to 3.5 tons - 12%.

In addition, at the first stage, according to video filming data, the average speed of movement at each of the sections and the modes of movement of the traffic flow were determined.

The average speed of movement according to the method was: public transport stop "SibADI" - 52 km/h; public transport stop "Medical Academy" - 57 km/h; public transport stop "Technical University" - 45 km/h.

Modes of traffic flow at each of the sections are presented in table 2 [16].
Table 2. Modes of traffic flow at observation posts.

| Observation post                  | Constant speed | Deceleration | Acceleration | Acceleration idling |
|-----------------------------------|----------------|--------------|--------------|---------------------|
| public transport stop "SibADI"    | 84%            | 0%           | 16%          | 0%                  |
| public transport stop "Medical Academy" | 57%        | 43%          | 0%           | 26%                 |
| public transport stop "Technical University" | 50%        | 0%           | 50%          | 0%                  |

The processing of statistics obtained from the gas analyzer for a 20-minute period was carried out with a step of 10 seconds (120 values). Further, on the basis of the obtained data, the average values of the concentration of CO in the surface layer of the atmosphere at the observation points for each series of measurements were determined (figure 4).

![Figure 4](image_url)

**Figure 4.** Average value of CO concentration at the points of the investigated segment of the Mira Avenue for a 20-minute measurement period: 1 - opposite public transport stop "SibADI"; 2 - before the public transport stop "Medical Academy"; 3 - for the public transport stop "Technical University".

Comparison of the average values of CO concentration with one of the criteria for atmospheric air pollution - the maximum permissible concentration of the pollutant (for CO: maximum permissible values of the maximum one-time = 5 mg/m³, the maximum permissible values of the daily average = 3 mg/m³) shows the excess of the average daily indicator at the point of measurements No. 1 (opposite the public transport stop "SibADI") in the morning period [18].

At the same time, for all measurement periods, the number of exceeding the maximum permissible maximum-one-time values was recorded, measurements taken at 09:00, 12:00, 15:00, 18:00:
- post No. 1 (public transport stop "SibADI") - 18 out of 120 values;
- post No. 2 (public transport stop "Medical Academy") - 6 out of 120 values;
- post No. 3 (public transport stop "Technical University") - 7 out of 120 values.

The dependence of the average concentration of carbon monoxide on the traffic intensity during the observation period at the survey points is shown in figure 5.
Figure 5. Dependence of the average concentration of CO on traffic intensity for the measurement periods at the points of the studied segment of the Mira Avenue: 1 - at wind speeds up to 9 km/h; 2 - at wind speeds up to 17 km/h.

The maximum CO concentration recorded for all observation periods on the investigated street segment (10.1 mg/m³ or 2.0 maximum permissible concentration values) is comparable to the maximum CO concentration recorded from traffic flows at checkpoint No. 7 of Kosmichesky prospect (maximum - permissible concentration values = 2.8). The highest maximum one-time CO concentration in the city of Omsk was recorded at checkpoint No. 2, Rabinovich street (maximum permissible concentration values = 4.1). These are data from state monitoring "Ob-Irtysh Administration for Hydrometeorology and Environmental Monitoring" [11, 19, 20].

4. Conclusion
The experimental studies carried out made it possible to fully assess the level of atmospheric air pollution of the city highway (Mira Avenue, the city of Omsk) under certain parameters of the traffic flow, traffic modes and meteorological conditions.

The analysis of the experimental results obtained in the course of office processing led to the following conclusions:

1. The level of atmospheric air pollution with CO in the main area of Mira Avenue is comparable to the level of pollution of other highways of the city with heavy traffic without freight transport in the stream.

2. The volume of emissions of pollutants (for example, CO) is not a definite function of the traffic intensity, and largely depends on the prevailing modes of traffic flow on a specific section of the urban highway segment.

3. An important factor influencing the level of atmospheric air pollution CO (gas, which is lighter than air) is the wind speed and direction [4].

References
[1] Donchenko V V, Kunin Yu I, Ruzsky AV and Vizhensky V B 2014 Methods for calculating emissions from vehicles and the results of their application Journal of Automotive Engineers 3 (M.: Publishing House AAI PRESS) pp 44-51
[2] Dyakov A B, Ignatiev Yu V, Konshin E P and Dyakov A B 1989 Ecological safety of traffic flows (Moscow: Transport) p 128
[3] Lukanin V N, Buslaev A P and Yashina M V 2001 Motor transport flows and the environment (Moscow: Infra-M) p 645
[4] Kulchitsky A R 2004 Toxicity of automobile and tractor engines (Moscow: Academic project) p 400
[5] Parsaev E V, Teterina I A and Kashtalinsky A S 2018 Estimation of atmospheric air pollution by traffic flows on street sections (on the example of the city of Omsk) *Bulletin of Irkutsk State Technical University* 8 181-8

[6] Parsaev E V 2017 Influence of the applied technical means of traffic management on the level of pollution of urban highways by traffic flows *II International scientific and practical conference: Architectural, construction and road transport complexes: problems, prospects, innovations* (Omsk: SIBADI) pp 165-8

[7] Parsaev E V, Malyugin P N and Teterina I A 2018 Methodology for calculating emissions of non-stationary traffic flows *Vestnik SibADI* (Omsk: SIBADI) 5 686-97

[8] Gorodkov A V and Kozonogina I V 2017 To the study and assessment of the state of the environment of the main territories of the city by the factor of motor pollution *Ecological safety of construction and urban economy* 1 53-60

[9] GOST 17.2.3.01. Protection of Nature. Atmosphere. Rules of air quality control of settlements 1987 (Moscow: Standartinform) p 4

[10] RD 52.04.667-200 Documents on the state of air pollution in cities for informing state bodies, the public and the public. General requirements for the development, construction, presentation and content 2006 (Moscow: Gidrometeoizdat) p 50

[11] Report on the environmental situation in the Omsk region for 2018 (Omsk: Omskblankizdad) p 318

[12] Teterina I A, Letopolsky A B and Korchagin P A 2020 Effect of tire dynamic characteristics on vibration load at the operator's workplace *Conference Series: Journal of Physics* 1441 012097

[13] GOST R 51256-2018 Technical means of traffic management. Road marking. Classification. Technical requirements 2018 (Moscow: Standartinform) p 63

[14] Volkov V S and Tarasova E V 2014 Monitoring of the urban environment taking into account the activities of motor transport *Modern problems of science and education* 2 20

[15] GOST 56162-2014 Air pollutant emissions 2014 (Moscow: Standartinform) p 12

[16] Methodology for calculating atmospheric emissions of pollutants by road transport on urban highways 1997 (Moscow: NIIAT) p 54

[17] Highway Capacity Manual *National Research Council* 2000 (USA: Washington) p 1134

[18] GN 2.1.6.3492-17 Maximum allowable concentration of pollutants in the air of urban and rural settlements Moscow 2017 (Moscow: Ministry of health of Russia) p 61

[19] Gekkieva S 2019 The assessment of air pollution of the city of Nalchik by road transport *IOP Materials Science and Engineering* 698 077068

[20] Chossière G P, Malina R A, Dedoussi I C, Eastham S D, Speth R L and Barrett S R 2017 Public health impacts of excess NOx emissions from Volkswagen diesel passenger vehicles in Germany *Environmental Research Letters* 12 034014