The assessment of air pollution of the city of Nalchik by road transport

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Abstract. This work is devoted to the assessment of the state of the air environment of the city - the surface layer of the atmosphere in which the most intense processes associated with the arrival of harmful substances occur. In complex processes of interaction of a large number of factors that determine the air quality at a particular time, the most important are the characteristics of emissions of harmful substances from sources of air pollution, as well as weather conditions affecting the spread of impurities. This study attempts to assess the role of air pollution from vehicles in Nalchik.

Introduction
The need for studies to assess the quality of the environment throughout the North Caucasus is not in doubt. It is primarily determined by the unique combination of the North Caucasus region as a resort and an important transport and industrial center of the South of The Russian Federation. In this situation, it seems relevant to study the issue of air pollution by road on the example of the city of Nalchik, i.e. the surface layer of the atmosphere in which the most intense processes associated with the receipt of harmful impurities and their transfer by air masses.

The main sources of pollutants into the atmosphere of Nalchik are industrial enterprises and vehicles. Each of these sources has its own characteristics and features. In the context of some decline in industrial production and a sharp increase in the number of cars, recently the role of road transport in air pollution has increased significantly and, according to a number of estimates, its contribution is now in total significantly exceeds the contribution of industry.

In 2010 the number of cars in the world exceeded 1 billion units, while maintaining such dynamics by 2040 it will reach 1.8 billion units. According to the results of the rating compiled by the Agency Alfa-insurance, the availability of cars in Russia is much lower than in developed European countries and the United States [9]. At the same time, it is increasing from year to year. Kabardino-Balkaria in this ranking takes 74 place with 213 cars per thousand inhabitants of the Republic. The situation is worse among the North Caucasus regions in the KCR (182), Dagestan (171), Ingushetia (142), Chechnya (131) at the end of 2016 (figure 1).

According to official sources, RIA "KBR" 2018 in the country there are 282 public transport routes: international-2inter-regional-51, inter-municipal-130, urban-65, intra-municipal-34.
Figure 1. Increase in the level of motorization of the North Caucasus Federal District from 2012 to 2022 according to «Alfa-Insurance» forecasts per 1,000 inhabitants.

Table 1. Fleet of cars in the North Caucasus Federal District in 2013.

| Region                   | Car Park Total thousand pieces | Foreign cars thousand pieces | Share of foreign cars, % |
|--------------------------|-------------------------------|------------------------------|--------------------------|
| Republic of Dagestan     | 532.8                         | 124.4                        | 23.4                     |
| Chechen Republic         | 192.3                         | 52.2                         | 27.1                     |
| Republic of Ingushetia   | 71.7                          | 20.9                         | 29.2                     |
| Kabardino-Balkarian Republic | 188.6                     | 60.5                         | 32.1                     |
| Republic of North Ossetia Alanic | 169.5                 | 57.6                         | 34.0                     |
| Karachay-Cherkess Republic | 90.5                        | 31.8                         | 35.1                     |

Methods and materials

The extent and characteristics of pollution, as well as the number of sources and emissions of pollutants, the amounts of impurities entering the atmosphere, vary considerably depending on the time of year and meteorological conditions. The dispersion of impurities in the air is influenced by such characteristics of pollution sources as the height of the emission (motor transport refers to ground sources of 2-4 meters) and the temperature of the emitted gas-air mixture. Due to the fact that chemical pollution from ground-based sources enters the lower layer of the atmosphere, and the process of their dispersion is significantly different from the process of dispersion of high stationary sources, harmful substances accumulate in the human respiration zone. From different sources it is known that one passenger car per day can emit into the atmosphere about one kilogram of various toxic substances that are able to stay in the environment for up to 5 years depending on meteorological conditions. Their environmental impact is enormous - the greenhouse effect (melting glaciers, climate change, etc.). Therefore, road transport should be classified as the most dangerous sources of air pollution.

Table 2. Emissions of pollutions from motor vehicles in 2017; thousand tons [12]

| Name of the region(city) | SO₂ | NOₓ | LONM | CO  | C  | NH₃ | CH₄ | Total |
|--------------------------|-----|-----|------|-----|----|-----|-----|-------|
| Kabardino-Balkarian Republic | 0.5 | 9.5 | 8.4  | 64.7| 0.2| 0.2 | 0.3 | 83.9  |
| Nalchik                  | 0.1 | 1.4 | 1.7  | 13.3| 0.022| 0.04 | 0.1 | 16.6  |
| In Russia as a whole     | 27.28 | 86.0 | 10.14 | 23.38 | 10.05 | 0.01 | 0.39 | 157.2 |

The combination of meteorological factors determines the ability of the atmosphere in a given geographical point to disperse and remove harmful substances entering it, and thus form some level of pollution. The following climatic conditions most significantly affect the level of air pollution: the direction and characteristics of transport and distribution of impurities in the atmosphere, the vertical distribution of temperature and wind speed, the amount and duration of precipitation contributing to leaching of impurities from the atmosphere, the intensity of solar radiation determining photochemical transformations of impurities. In cities with a large number of small and large enterprises, in the
presence of a large number of vehicles, the influence of meteorological conditions on the dispersion of impurities depends on the ratio of low and high emission sources, on heated and cold emissions [1]. In addition to meteorological conditions, the dispersion of harmful substances in the surface layer of air is largely influenced by the architectural features of the city: the orientation and width of highways and streets. The height and location of buildings and structures, green areas and water bodies, which are different forms of ground obstacles to air flow, which can lead to the occurrence of specific meteorological conditions in the city. As observations [2] show, even with constant volumes of industrial and transport emissions as a result of the influence of meteorological conditions, the levels of air pollution in the same territory can differ several times. Features of the wind regime play an important role, since the orientation of most highways and streets of the city coincides with the direction of the prevailing transfer of air masses from south-west to north-east and back. On the one hand, it contributes to the summation of the areas of pollution of different industrial zones of the city, and on the other hand, it ensures the removal of pollutants by the winds beyond the city limits.

**Table 3.** Specific mileage emissions of pollutants \( M_{i,k} \), g/km for various categories of vehicles.

| Name categories cars, Category number | CO | \( NO_x \) | CH | Soot | \( SO_2 \) | formaldehyde | benz\( \_p \) pyrene |
|--------------------------------------|----|----------|----|------|----------|---------------|----------------|
| Passenger cars I                     | 0.8| 0.3      | 0.24| 0.5\( \times \)10\^\(-2\) | 0.6\( \times \)10\^\(-2\) | 1.4\( \times \)10\^\(-3\) | 0.16\( \times \)10\^\(-4\) |
| Passenger cars, Vans minibuses up to 3.5 t II | 4.2| 1.6      | 0.63| 3.4\( \times \)10\^\(-2\) | 1.3\( \times \)10\^\(-2\) | 2.3\( \times \)10\^\(-3\) | 0.18\( \times \)10\^\(-4\) |
| Cargo from 3.5 to 12 t III           | 4.8| 5.8      | 1.4 | 0.34 | 2.4\( \times \)10\^\(-2\) | 0.6\( \times \)10\^\(-2\) | 0.54\( \times \)10\^\(-4\) |
| Cargo over 12 t IV                  | 5.1| 6.8      | 1.8 | 0.40 | 3.5\( \times \)10\^\(-2\) | 0.7\( \times \)10\^\(-2\) | 0.66\( \times \)10\^\(-4\) |
| Buses over 3.5 t V                  | 3.6| 4.3      | 0.4 | 0.14 | 2.0\( \times \)10\^\(-2\) | 0.2\( \times \)10\^\(-2\) | 0.18\( \times \)10\^\(-4\) |

Carbon monoxide (or carbon monoxide) is one of the most toxic products in the exhaust gases of a hydrocarbon-powered vehicle. Although he himself does not belong to substances that cause the greenhouse effect, but easily reacts with atmospheric oxygen, with hydroxyl radicals, forming carbon dioxide. Air pollution with nitrogen oxides and acid rain cause great harm to human health, as well as the plant world. The content of toxic substances in the exhaust gases depends on the mode of operation of the engine.

**Table 4.** Pollutants and MPC.

| Pollutants         | MPC Max. single, \( ml/m^3 \) | MPC daily | Toxicity class |
|--------------------|-------------------------------|-----------|----------------|
| Carbon monoxide    | 5.0                           | 3.0       | 4              |
| Nitrogen oxides    | 0.4                           | 0.06      | 3              |
| Soot               | 0.15                          | 0.05      | 3              |
| Non-toxic dust     | 0.5                           | 0.15      | 3              |
| Sulphur dioxide    | 0.5                           | 0.15      | 3              |

**Table 5.** Content (%) of harmful substances in exhaust gases.

| Harmful substances | Operation mode |
|--------------------|----------------|
|                    | Idling | Constant speed | Acceleration from 0 to 40 km/h | Slow from 40 to 0 km/h |
| Carbon oxides      | 0.5-8.5 | 0.3-3.5 | 2.5-5.0 | 1.8-4.5 |
| Hydrocarbons       | 0.03-0.12 | 0.02-0.6 | 0.12-0.17 | 0.23-0.44 |
| Nitrogen oxides    | 0.00-0.01 | 0.1-0.2 | 0.12-0.19 | 0.003-0.005 |
Results

Table 6. Intensity (units / h) and composition of traffic on the main streets of Nalchik: in 2002 (numerator) and in 2018 (denominator).

| Street, place of observation                        | Total  | Cars     | Trucks   | Buses  | Minibuses |
|----------------------------------------------------|--------|----------|----------|--------|-----------|
| St.Kabardinskaya, the intersection with st.Idarov (Gagarin) | 1836/2874 | 1491/2385 | 105/136 | 63/88  | 177/265   |
| St.Malbakhova                                      | 1593/2334 | 1080/1620 | 120/132  | 75/105 | 318/477   |
| Etc.Lenin, the intersection with st.Tolstoy         | 1449/2158 | 1212/1818 | 18/15    | 30/42  | 189/283   |
| St.Kirov, the intersection with st.Malbakhov        | 1428/2089 | 1113/1670 | 117/125  | 27/38  | 171/256   |
| St.Ossetian intersection with st.Shogentsukova      | 1380/1925 | 963/1348  | 96/101   | 48/67  | 273/409   |
| St.Keshokova, the intersection with st.Shogentsukova | 1326/2076 | 1095/1752 | 51/56    | 24/34  | 156/234   |

As shown in table 6, the results of field studies for 2002 [5] and 2018, the difference between the highways of Nalchik in terms of intensity and nature (composition) of the traffic flow is quite significant. On-site surveys of the structure and intensity of motor transport flows with a subdivision according to the main categories of vehicles were determined in accordance with GOST 32965-2014 “Public roads. Methods of accounting for the intensity of traffic flow”. High-speed traffic on the streets of Nalchik varies between 40-80 km h and more. The actual and estimated traffic intensity should be taken in total in both directions. The composition of the movement significantly affects the capacity of the highway. It must be taken into account in all calculations related to the assessment of the level of service traffic and bandwidth. The composition of the movement on the road is determined on the basis of data of automated or visual accounting of movement. During the day, two distinct periods of increased traffic intensity can be distinguished: internal at the beginning of the working day and evening at the end of the day. These periods are called peak hours, and during them occurs 10-12% of the daily volume of movement. In the busiest sections along the streets of Malbakhov, Idarov, Kabardinskaya during daytime during rush hour, more than 7297 cars pass in both directions, traffic jams of 5-7 minutes are periodically created. On the streets of Lenin, Ossetian, Keshokov (Soviet), Shogentsukova traffic intensity is 6159 cars per hour [3]. Listed highways form the basis of the transport frame of the city. This paper addresses the issue of pollution of the city of Nalchik from a moving vehicle. As the main software tool for calculating emissions of pollutants into the atmosphere, the “Motor Transport Enterprise” program developed by Ecocentre was used in accordance with the methodological documents approved for use in 2018 [4,5]. The results of calculations of atmospheric pollutants from motor transport for the three busiest highways of the city are presented in tables 7-9.

Table 7. Characteristic of emissions of pollutants into the atmosphere from vehicles on the site: Kabardinskaya-ul. Idarova

| Code | Pollutant            | Maximum one-time release, g/s | Annual emission, t/year |
|------|----------------------|-------------------------------|-------------------------|
| 301  | Nitrogen dioxide     | 0.0072747                     | 0.0024198               |
| 304  | Nitrogen (II) oxide  | 0.0011821                     | 0.0003932               |
| 328  | Carbon               | 0.0003875                     | 0.0000361               |
| 330  | Sulfar dioxide       | 0.001705                      | 0.0006293               |
| 337  | Carbon oxide         | 0.33759                       | 0.1018547               |
| 415  | Hydrocarbons limit C1-C5 | 0.0625167                 | 0.0093195               |
| 2704 | Gasoline (petroleum) | 0.0329633                     | 0.0049573               |
| 2732 | Kerosene             | 0.0018083                     | 0.0001423               |
To assess the degree of negative impact of emissions of pollutants into the atmosphere, calculations are performed according to the UPRZA Ecolog-4.5 software approved in the prescribed manner, which implements the provisions of methods for calculating the dispersion of pollutants in the air [6].

Table 8. Characteristics of emissions of pollutants into the atmosphere from vehicles on the site: st. Keshokov Str. Shogentsukova.

| Code | Pollutant            | Maximum one-time release, g/s | Annual emission, t/year |
|------|----------------------|------------------------------|-------------------------|
| 301  | Nitrogen dioxide     | 0.007904                     | 0.0021016               |
| 304  | Nitrogen (II) oxide  | 0.0012844                    | 0.0003415               |
| 328  | Carbon               | 0.0003483                    | 0.0000329               |
| 330  | Sulfur dioxide       | 0.0018525                    | 0.0005547               |
| 337  | Carbon oxide         | 0.366795                     | 0.078426                |
| 415  | Hydrocarbons limit C1-C5 | 0.067925               | 0.0062281               |
| 2704 | Gasoline (petroleum) | 0.0182875                    | 0.0046664               |
| 2732 | Kerosene             | 0.0016256                    | 0.0001282               |

Table 9. Characteristic of emissions of pollutants into the atmosphere from motor transport on the site: pr. Kirov-ul. Malbakhova.

| Code | Pollutant            | Maximum one-time release, g/s | Annual emission, t/year |
|------|----------------------|------------------------------|-------------------------|
| 301  | Nitrogen dioxide     | 0.0070542                    | 0.0018063               |
| 304  | Nitrogen (II) oxide  | 0.0011463                    | 0.0002935               |
| 328  | Carbon               | 0.0002713                    | 0.0000265               |
| 330  | Sulfur dioxide       | 0.0016533                    | 0.0004653               |
| 337  | Carbon oxide         | 0.32736                      | 0.0684285               |
| 415  | Hydrocarbons limit C1-C5 | 0.0606222               | 0.0056918               |
| 2704 | Gasoline (petroleum) | 0.0180833                    | 0.0038244               |
| 2732 | Kerosene             | 0.0012658                    | 0.0001032               |

This site is located in the Central part of the city near the resort Park. The source of air pollution (ISA No. 0001) is vehicles moving along the highway, from which pollutants enter the atmosphere during the combustion of fuel. Calculation of atmospheric air pollution was performed at the design site with a width of 310 m with a step of 10 x 10 m. The boundary of the near residential zone from the highway (15m) and the data given in the tables VIII-XII are considered as calculation points. Dangerous wind speed is 0.65 m/s.

According to these methods, calculations of surface concentrations of pollutants (MPC share) in the design points are carried out. The calculation of atmospheric air pollution were performed for points located on the boundary of a residential zone on sites of the highways Keshokova-Shogentsukova and Torres-writer and artist. The concentration of nitrogen dioxide is 0.11-0.16 MPC, nitrogen oxide 0.01 MPC, sulfur dioxide 0.01 MPC, carbon monoxide 0.21-0.29 MPC, gasoline 0.01-0.02 MPC, the concentration of the summation group of nitrogen dioxide and sulfur dioxide 0.08-0.1 MPC, respectively. The obtained data of emissions of pollutants by motor transport on urban roads of the resort city of Nalchik do not exceed the MPC. These data can also be used in the summary calculations of polluting the air of the city emissions of harmful substances from industrial facilities and transport [8].

Conclusion
Calculations of dispersion of pollutants in the surface layer of the atmosphere showed that the concentrations of harmful substances from vehicles do not exceed the maximum permissible values of these substances. However, even such a rather brief analysis of the dispersion of pollutants in the air
leads to the conclusion that motor transport is not the last place in the air pollution of Nalchik (16.6 thousand tons in 2017).

Unfortunately, not having observing system for weather parameters and the quality of the air environment in Nalchik difficult to continue further the study of this topic. However, if visual observations and air sampling are synchronized during instrumental measurements, more accurate results can be obtained and a map of the migration of pollutants from vehicles across the city can be drawn. It is hoped that this work will be useful in addressing the challenges of assessing and improving Nalchik's environment.

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