Analysis of air pollution and noise on low-speed streets

S V Maksimova¹, G M Batrakova²

¹Urbanistics Department, Perm National Research Polytechnic University, 29, Komsomolsky Ave. Perm 614990, Russia
²Department of Environmental Protection, Perm National Research Polytechnic University, 29, Komsomolsky Ave. Perm 614990, Russia

E-mail: svetlana-maximova@yandex.ru

Abstract. The growth of motorization led to significant changes in the traffic regime on the peripheral streets of big cities. With the transition to market economy, the lower floors of housing stock are massively used for commercial activities. The width of the roads profile is narrowed due to the growth of parallel parking and double-parking. This leads to a decrease in the speed traffic through the streets in residential areas with a significant increase in its intensity. The purpose of the paper is the research of environmental consequences of increasing traffic intensity on residential streets in Perm, especially in the locations of schools and kindergartens. The article presents the main parameters, conditions of full-scale experiments and the results of air pollution measurements and acoustic environment. There are also the values of carbon monoxide, formaldehyde and other air pollution. The study shows that the intensity of traffic at low speed in winter does not affect air pollution. The noise level increases at the intensity of more than 400 units/hour. The results prove the need to study the ecological state of low-speed streets in the development of urban planning documentation and land use as well as development rules.

1. Introduction

Transport flows are considered to be a priority source of harmful substances and an acoustic impact factor in urban areas. The number of vehicles is steadily growing which in turn requires the solution of interdependent problems in the formation of favorable and safe urban environment.

The number of cars per Perm population has a tendency of steady growth. In 2015, there were 242 thousand vehicles, in 2017 this figure increased to 246.5 thousands. For comparison, by the beginning of 2006 the number of registered vehicles was 218.3 thousands, the increase in the number of cars in the period 2008 - 2013 increased by 32.5 %, and over the past 5 years - by 34%. According to Russian Federation Sanitary norms educational institutions have to be placed in intra-residential areas of residential neighborhoods at a distance that provides noise levels below 50 dB (equivalent) and 70 dB (the maximum level of sound) and air pollution level not higher than MPC.

A large volume of scientific and technical literature is devoted to environmental problems of major highways and air pollution assessment of the street and road network (SRN) in central areas of cities with high traffic intensity (from 2000 auth./h) [1-3]. Due to the stereotype of a smaller expected scale of harmful transport impact, insufficient attention is paid to the peripheral areas of the SRN (roads, streets and roads of local importance). At the same time, the growth of motorization has led to significant changes in the traffic regime on these streets. The lower floors of housing stock are actively
used for commercial activities (salons, shops, pharmacies, etc.), so the width of the road profile is narrowed by parked cars and double-parking. This contributes to low speed of traffic on the streets in residential areas with a significant increase in its intensity. A considerable contribution to this process is made by changing traffic of personal transport, due to daily fluctuations of transport correspondence in residential areas, where children's educational institutions are located. The study of environmental aspects of speed reduction at high traffic intensity is interesting from the point of view of the global trend regarding speed changes in cities and ensuring the development of pedestrian and bicycle use as indicators of safe urban environment [4,5]. The speed of traffic (traffic flow) in Russian cities tends to decrease, the reason for which is growing motorization on the background of low capacity and density of street and road network [6,7]. The average speed of vehicles on the streets located outside central districts of Perm was 30 km/h, for central districts – 7 - 20 km/H2 [8].

The aim of the work was to study some characteristics of the urban environment quality in some SRNs in such streets, where there is traffic and speed limit of 20 - 40 km/h. The research involved the use of some methods of theoretical and methodological analysis, measurements of air pollution and noise exposure. This article presents final results of field studies.

2. Materials and methods

For full-scale studies, the territories with secondary schools and kindergartens that generate the most intense traffic flows at low speeds during peak hours and which are located either within blocks or on their borders have been chosen, Figure 1.

Educational institutions located on the main streets were not considered due to the fact that such a location of schools and kindergartens is unusual for streets with heavy traffic, and the structure of traffic flows on such streets is difficult to formalize.

The studies were carried out in the autumn-winter period of 2018, the measurements were made on weekdays during peak traffic loads in peripheral sections of SRN. The periods of measurements were chosen based on the analysis of previous studies on the structure and intensity of traffic flows in Perm, which determined the largest number of cars in the morning rush hour from 9-00 to 10-05 and evening rush hour - from 17-30 to 18-30. [8]. In our studies, the intensity of traffic was determined by using video equipment directly counting transport units on residential streets. Air sampling was carried out during the intervals from 9.00 a.m. to 11.30 a.m. and 4.30 p.m. to 7.00 p.m. The territories where the research was conducted are located in the residential area of the city central districts. The main streets of the city were not the subject of the study.

To assess the level of air pollution, sampling and quantification of the content of carbon monoxide, nitrogen oxides, suspended particles and fine dust (PM10,PM2, 5), formaldehyde and polyaromatic hydrocarbons were performed [9]. Air sampling was carried out in series of 30 minutes.

One of the aspects of transport impact evaluation is determination of noise level. To assess the noise impact, measurements were made with the noise meter Center 325 (2-nd class of accuracy).

Road sections located next to a pre-school or educational institution have been identified for measurements. Noise level measurements were carried out at the nearest open area to the source of noise. The noise meter was placed on the sidewalk at a distance of 7.5±0.2 m from the axis of the first lane; at a distance of 50 m from intersections and stopping points of public transport. Measurements were carried out at a steady speed of vehicles, The microphone was placed in the direction perpendicular to the movement of the traffic flow at a height of 1.5±0.1 m from the pavement of the roadway cover.

Measurements of equivalent noise level (LAeq, dBA) were performed during daytime discretely, excluding the periods of unusual manifestations of noise (aviation noise, noise from railway transport movement, etc.). The obtained values were compared with the acceptable value of the equivalent sound level (PSL=55 dBA) in residential and educational institutions areas at daytime, specified by the SN 2.2.4/2.1.8.562-96 "Noise in the workplace, in living and public buildings as well as in residential areas."
3. Results and discussion

Studies have revealed the content of carbon monoxide, formaldehyde and suspended solids in the air. Their concentrations do not exceed the acceptable maximum values of onetime concentration (MPC). The content of nitrogen dioxide, sulfur dioxide and Benz (a) pyrene in the air amounts to the concentrations below the detection limits of measurement techniques. At the same time it should be noted that for some population categories including preschool and school age groups, harmful effects of air pollutants are possible in concentrations close to the recommended safe values.

The results are shown in table 1.

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**Table 1.** Content of pollutants in air samples.

| Name                        | Maximum permitted concentrations (MPC) of toxic substances in air, mg/m³ | The content of pollutants with regard to category of streets, mg/m³ |
|-----------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------|
| Carbon monoxide             | 5,0                                                                       | 0,96 ± 0,75                                                     | < 0,75                                                        |
| Formaldehyde                | 0,05                                                                      | 0,003 ± 0,0006                                                  | < 0,001                                                       |
| Total Suspended particulate matter (or TSP) | 0,5                                                                       | 0,125 ± 0,030                                                   | 0,162 ± 0,004                                                 |
| Nitrogen dioxide            | 0,2                                                                       | Less than 0,1                                                   |                                                               |
| Sulphur dioxide             | 0,5                                                                       | Less than 0,03                                                  |                                                               |
| Benz (a) pyrene             | 0,1 * 10⁻⁶                                                                | Less than 0,5 * 10⁻⁷                                           |                                                               |

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*Figure 1.* The scheme of educational institutions location in residential buildings, taking into account the territory adjunction to driveways/streets. A) The object is inside the quarter, the territory is adjacent to the yard areas and to the quarter driveways/streets. B) The object is on the border of the quarter, the area is adjacent to the streets of district status.
The suspended particles concentration was established in all studied air samples. The obtained values specify air dustiness in winter and these values can be substantially higher in summer. Differences between indices of dust particles dispersion showed that the proportion of the smallest particles (PM2.5) relative to larger (PM10) varied in a wide interval (5-53%). The contents of fine dust (PM10, PM2.5) are higher than the lower limit of detection (0.001 mg/m³). See Table 2.

Table 2. The contents of solid dust particles in air samples

| Dust particles | MPC, mg/m³ | Multiplicity of MPC excess with regard to intensity of cars movement (unit/h) |
|---------------|------------|--------------------------------------------------------------------------|
|               | ≤ 500      | 500 – 1000                                                               |
| TSP           | 0,5        | 0,25                                                                     |
|               | 0,3        | 0,08                                                                     |

The values are comparable with the results of hygienic assessment of air environment in major cities of the country at the crossroads of highways and bus stops on citywide streets [10-15]. When averaged over a 20 minute interval, the concentration of PM2.5 and PM10 did not exceed MPC. There is no evident correlation between the contents of dust and the number of vehicles. The concentration of fine dust in the air is uniform for all parts of the SRN, not related to the category of roads and the intensity of traffic flows (Figure2). Low concentrations of pollutants can be associated with the natural self-purification processes of air in winter, the results must be supplemented by observations in other periods of the calendar year.

![Figure2](image.png)

Figure2. The concentration of fine dust in the air for different objects (schools and kindergartens).

The intensity of traffic flows in Perm, as in any another major city, depending on the time of day, the days of the working week and the time of year. In the city center the highest intensity was noted in the morning (8:00-9:30) and in the evening (17:00-19:30). Most intensity indicators are observed on working days of the week – from Monday to Thursday, which can be explained by the increased business activity of the population on weekdays, weekends intensity is noticeable decreases, and on Sunday there is a minimum level intensities. The annual dynamics of traffic flows the intensity varies by season: the freest city roads are in summer (July-August), when many motorists are leaving the city. [3]
Passenger-cars are dominated in the Perm traffic flows; their share was more than 80% in total for the selected areas and more than 90% on of quarterly roads. The share of vans and other commercial vehicles did not exceed 5%, but this category of vehicles was noted at all observation sites. The share of public transport, primarily buses, was 10-14%.

Assessment of the exceedance of the acceptable exposure level on the streets with low speeds and high traffic volume of vehicles is presented in table 3.

Table 3. Characteristics of noise pollution on residential streets.

| Parameter                          | Control points of SRN |
|------------------------------------|------------------------|
|                                    | 1 | 2 | 3 | 4 | 5 | 6 |
| The intensity of the movement, unit/hour | 372 | 444 | 796 | 637 | 436 | 436 |
| Share of passenger transport, %    | 96,7 | 97,3 | 79,2 | 98,2 | 98,2 | 87,1 |
| LAeq, dBA                          | 48,8 | 52,0 | 60,9 | 61,3 | 54,1 | 59,0 |
| Exceeding remote control           | -   | -   | 5,9 | 6,3 | -   | 4,0 |

Exceeding the acceptable level of noise exposure by an average of 5.5 dBA is typical for central areas in peripheral sections of SRN with traffic intensity of more than 430 cars per hour [16-19].

It should be noted that planting (trees and shrubs) on residential streets in winter is not an obstacle to the propagation of sound waves. It does not reduce the intensity or absorption of sound pressure level, nor does it increase the gap between noise source and noise recipients. The practical significance of the study is to obtain data for the development of organizational and technical measures for the formation of an acoustically comfortable environment, required for educational and scientific institutions [18-20].

4. Conclusions
The results have shown there are not significant changes in the indicators of assessing the quality of atmospheric air including dust particles of different degrees of dispersion if the traffic intensity increases in peripheral sections of Perm central streets. The noise impact of vehicles exceeded the acceptable levels of exposure in the residential area at the intensity of more than 430 cars/hour.

It is possible that the low content of pollutants in air samples is due to processes of natural self-purification of air from suspended particles and gases in winter. It is known that regular precipitation as well as low temperatures of air masses contribute to processes of atmospheric air self-purification, and weak insolation during a short winter day prevents the formation of photochemical toxicants.

Along with that, one can assume that dust level will increase appreciably in warm season.

Obviously, to verify the results of air pollution level, it is necessary to carry out more actual measurements during the year to check dynamic mobility of the air environment and the expected variability of the results for the controlled substances.

The obtained data of the dust level in residential areas air and the increased noise level in winter are largely related to the quality of the road surface. Peripheral streets in Perm have asphalt pavement. Due to sharp changes in winter temperatures, the use of cheap anti-icing materials and frequent patchwork, it quickly becomes unusable and turns to be a source of negative impact on the environment along with vehicles.

The accumulation of the data on traffic intensity and characteristics of urban environment quality will allow to objectively review the size of any profile streets, to compare them with the existing urban standards regarding street lines, SRN setbacks, noise protection measures and road safety rules. As it has already been proven by the experience of many major cities around the world, the combination of these activities helps to improve the availability of social facilities, stimulates walking and cycling, reduces population dependence on the car and has a positive impact on environment safety.
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