Influence of transport noise on living environment in New Moscow

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Abstract. The article considers problems of increasing traffic noise in the territory of New Moscow. The increase in traffic flow during the reconstruction of the Kaluga highway led to the expansion of the acoustic discomfort zone. The actual norms of permissible noise levels were violated in many low–rise buildings settlements of New Moscow. The study object was the settlement of Desenovskoe, as the inhabitants of settlement began to note the increase in discomfort associated with the reconstruction of the highway. However, there were no protective measures for this settlement according to the reconstruction plan. Students under the guidance of Moscow state University of Civil Engineering lecturers carried out instrumental measurements and analysis of the traffic noise level. A comprehensive detailed approach to measurement is distinctive feature of this research. 28 characteristic measuring points were chosen in the territory of the settlement and on its border. The location of the points was chosen taking into the lie of the ground and the distribution of the traffic flow. The measurements were carried out in parallel along the Kaluga highway, on access roads and inside Desenovskoe settlement. Instrumental research was conducted both in the daytime and at night. The daily measurements were carried out on Monday and Friday (the days of the greatest congestion of highways in this locality), night measurements were on Wednesday. In addition, the intensity and composition of the traffic flow were calculated. Equivalent and maximum sound levels in dBA, and the average and maximum sound pressure levels in dB were determined by the results of the studies and based on calculations. Significant norms’ deviations for the permissible noise level for populated areas were revealed both for the daytime and for the nighttime period. These results became the basis for creating noise propagation maps and determining zones of acoustic discomfort in Desenovskoe settlement. The zone of acoustic discomfort spread about 400 m deep into the territory of the settlement. Half of the residents were in the zone of acoustic discomfort.

1. Introduction

The most ambitious project to expand the territory of Moscow city was implemented in 2012. Moscow increased its territory 2.4 times due to expansion in the south–west direction. It is natural that such a rapid expansion of the city’s borders entailed a series of difficulties. The main problem is an increase in automobile traffic. New Moscow development plan includes a two–fold increase in length of roads and highways. At the same time, the main transport artery between the capital and New Moscow will remain Kaluga highway.

One of the main source of harmful impact in cities remains road transport. It is also an important
factor in the impact of roads on the environment, the noise from the moving traffic [1, 2]. Almost every urban resident continuously or periodically experiences various harmful acoustic influence [3]. They do not just cause discomfort, but also lead to serious illnesses. Cardiovascular diseases, hearing impairment, mental disorders, memory impairment, etc. are consequences of acoustic pollution effect. After the inclusion of territories of Moscow region in Moscow city, the relevance of the analysis of acoustic discomfort zones increase in the new areas is becoming increasingly evident [4–6].

In 2015, Department of urban planning policy of Moscow appealed with a request to rectors of Moscow higher educational institutions of the building profile. In this appeal, the Department asked "to involve some students and postgraduate students of universities in the research work aimed at solving practical problems of the Moscow construction complex". Special attention in the letter was given to the following issues: "the development of New Moscow: a comfortable living environment", "a list of minimally necessary organizational and technical measures to protect the environment at all stages of various objects construction", "problems of regulating the urban development of the territories attached to Moscow", etc.

As a response to this letter, the group of Moscow state University of Civil Engineering students and lecturerers carried out a comprehensive work to study the noise level, assess the zone of acoustic discomfort and conduct a complex of noise protection measures on the territory of New Moscow.

2. Materials and methods

The object of the study was the settlement of Desenovskoe. The settlement is a small town with low-rise residential buildings. The population of the settlement is about a thousand people. Kaluga highway passes and Desna river flows through the territory of the settlement. Crossing over the river is an automobile bridge. The settlement is in a low place relative to the highway. The residents began to note the increase in discomfort from the noise associated with the increase in traffic during the reconstruction of the Kaluga highway. These people complained about the constant rumbling inside the settlement. The residents noted the greatest level of discomfort at night and in the morning. At the same time for this area there are no protective measures for the highway reconstruction plan.

Desenovskoe settlement was not chosen by chance. This object is interesting from the point of view of character of traffic noise distribution. Relief features along the highway create both barriers to noise propagation in the form of small mound, and open and low areas for unobstructed propagation of noise. The Central street (Old Kaluga highway) of the settlement, running parallel to the Kaluga highway, allows us to more fully assess the distribution of acoustic discomfort zone within the residential area of the object of study. In addition, Penino–Desna road passes within the boundaries of the settlement. This road connects the Kaluga and Kiev highways and has a high traffic density. Also there are two traffic lights (at the entrance and at the exit from the settlement boundaries), which can contribute to the appearance of tonal noise on this section of the Kaluga highway. As a result, research on the territory of this settlement is a difficult and complex task.

One of the most important parameters in the study of transport noise is the choice of the date and time of testing. We chose the days and time of the maximum traffic density for carrying out full-scale noise measurements along the Kaluga highway, the Penino–Desna road, and the Central street (Old Kaluga highway). The highest statistical traffic congestion is observed on Friday and Monday in this direction. The main Friday traffic flow moves from the center of Moscow in the direction of the region, while "rush hours" fall on the interval from 17.00 to 20.00 hours. The opposite picture takes place on Monday. The flow of cars rushes to the center of the city, with a maximum traffic density from 7.00 to 11.00 hours. Transport noise monitoring was carried out three times. Daily measurements were carried out on Friday, November 27, 2015 from 17.30 to 20.00 and Monday, 30 November 2015 from 8.00 to 10.30. Night measurements were carried out on Wednesday April 20, 2016 from 3.50 to 5.50.

The location of the measurement points was chosen based on the most characteristic state of the noise regime created by the transport flows. A total of 28 measurement points were selected. The measurement points were distributed in such way as to obtain the most complete picture. There were 12 points along the Kaluga highway, 8 points along the Central street and 3 points along the Penino–Desna road.
Besides, additional measurements in octave bands were made at 5 points at the confluence of traffic flows and near traffic lights (figure 1).

![Figure 1. Location of measurement points: 1–12 – points along the Kaluga highway, 13–20 – points along the Central street, 21–23 – points along Penino – Desna road, 24–28 – points of traffic flows confluence and traffic lights.](image)

Both groups were provided with all the necessary equipment and are supplied with the forms of protocols for filling. Noise measurements were made in accordance with State standard 53187–2008 «Noise monitoring of urban areas». As the main measuring instruments used second class sound level meters Testo 816–1. The measuring sound level meter with a microphone was located at a height of 1.5 m and at a distance of 7.5 m from the axis of the nearest traffic lane. The microphone had a direction from the settlement towards the road. At least 10 measurements in 5 minutes were done at each point. Estimation of automobile traffic density and composition at a given point was carried out in parallel with the measurement of noise. This was done to monitor the results of the study. That is, one of the students considered the number of cars, trucks, buses and motorcycles that traveled during the noise measurement period.

During the measurements, the weather factor was also taken into account. During the study, the wind speed did not exceed 2 meters per second with an allowable value of 5 meters per second. But wind gusts were possible along the major highways. Sound level meters were equipped with wind protection to avoid distortion of data during measurements. Precipitation was not observed these days, the humidity was high – 80–95%, but the condensate was absent, the air temperature did not drop below -3ºC.

Particular attention was paid to measurements at the confluence of traffic flows and at traffic lights. Such locations can contribute to the appearance of tonal sound. Tonal sound is characterized by a significant excess of one of the frequencies. The source of this noise can be suddenly stopping or accelerating cars. First–class sound level meter Ecophysics–110A was used to measure sound pressure in octave bands on these sections of roads [7]. The measurements were made using the following mean geometric frequencies of the octave bands 63, 125, 250, 500, 1000, 2000, 4000 and 8000 Hz. Noise is considered a tonal sound, if in measurements in one–third octave bands the excess of the sound pressure
level in one band above neighboring ones is higher or equal to 10 dB. Based on the results of the measurements presented in Table 1, it can be seen that the noise in these areas is not a tonal sound and does not in itself affect the increase in the discomfort level.

Table 1. Noise level in octave bands. Point 28 (night time).

| Values | The average geometric frequency of octave bands, Hz | Average sound pressure level, dB | Maximum sound pressure level, dB |
|--------|-----------------------------------------------|---------------------------------|---------------------------------|
| Measured sound pressure levels, dB, in octave bands and measured sound levels, dB | 50.0 | 47.2 | 48.9 | 48.8 | 47.7 | 43.7 | 41.3 | 41.0 | 47.1 | 50.0 |
| Correction K₁, dB | 0 |
| Correction K₂, dB | 0 |
| Correction K₃, dB | 0 |
| Correction K₄, dB | 0 |
| Correction K₅, dB | 0 |
| Corrected average sound level, dB | – | 47.1 | 50.0 |
| Average expanded measurement uncertainty, dB | 2.8 |
| Estimated sound level, dB | – | 49.5 | 52.8 |

3. Results
The maximum and equivalent sound or noise levels were determined from the results of the study at each of the measured points for day and night measurements. The equivalent level of sound is the time-averaged sound pressure level. The values obtained were corrected by the origin of the noise, the nature of the noise source and the time of day (State standard 53187–2008. Noise monitoring of urban areas).

Analyzing the results of calculations, the following conclusion was made. The difference between the equivalent and maximum sound levels does not exceed 15 dBA. The maximum permissible values for the equivalent sound level are 55 dBA in the daytime and 45 dBA at night, and for the maximum – 70 dBA in the daytime and 60 dBA at night. The difference between the standard levels is 15 dBA, which is greater than the difference between the measured equivalent and the maximum sound levels (Table 2). Therefore, this equivalent level of sound can be identified as the most unfavorable factor.

The parameters of corrected equivalent sound level became the baseline data for constructing noise maps for the residential area of the Desenovskoe settlement. Noise maps serve to evaluate the existing noise regime taking into account the impact of the relief and are performed to eliminate, prevent or reduce the harmful effects of road transport noise on human beings and the environment. Noise maps allow us to visually assess the acoustic discomfort zone [8–10]. Exceeding the maximum permissible level of noise in residential area at the time of night measurements reaches 20 dBA, as can be seen from the calculation. Maps of exceedances of the maximum permissible noise level are given for nighttime as a more stringent criterion (figure 2).
Table 2. Noise level at point 5 (nighttime).

| Values                                      | Average sound level, dBA | Equivalent sound level, dBA | The maximum sound level, dBA |
|---------------------------------------------|--------------------------|----------------------------|-----------------------------|
| Average measured sound level, dBA           | 81.2                     | 82.0                       | 86.0                        |
| Correction K₁, dBA                         | 0                        |                            |                             |
| Correction K₂, dBA                         | 0                        |                            |                             |
| Correction K₃, dBA                         | 0                        |                            |                             |
| Correction K₄, dBA                         | 0                        |                            |                             |
| Correction K₅, dBA                         | 0                        |                            |                             |
| Corrected average sound level, dBA         | 81.2                     | 82.0                       | 86.0                        |
| Average expanded measurement uncertainty, dBA | –                        | 4.2                        |                             |
| Estimated sound level, dBA                 | –                        | 86.2                       | 90.2                        |

Figure 2. The noise map of a residential area in Desenovskoe settlement at the night.

On the noise map it can be seen that the zone of acoustic discomfort is about 400 m deep into the territory of the settlement. Thus, half of all residents are in the zone of harmful impact of traffic noise. Expansion of this zone will be observed after the reconstruction of the Kaluga highway and an additional increase in traffic flow [11, 12].

4. Conclusion
Based on the results of the work done, the following conclusions can be drawn:
  • The number of cars on the roads has sharply increased, especially freight transport in the territories attached to Moscow. This led to an increase in the zone of acoustic discomfort. The scientific study of this problem showed that residents of many settlements of New Moscow were in the zone of ecological disaster.
  • The scientific component of the study is a comprehensive, detailed approach to the study of the propagation of transport noise. New detailed approach to the choice of research object allowed taking into account a number of factors affecting the acoustic discomfort zone size. The study took into account
the following factors: terrain relief, peak traffic flow intensity, time and dates of measurements, traffic flows merging and composition, presence of traffic lights, weather factor, origin and nature of the source of noise.

• Analysis of the results of scientific research has shown that the greatest excess of the maximum permissible level of noise in residential buildings is achieved at night. The excess of the normative values at night was 20 dBA at the time of the study. An acoustic discomfort zone is 400 m deep into the territory of the settlement.

• It is mandatory to implement measures to protect against traffic noise (taking into account the prospect of increasing traffic flow) in the territory of New Moscow. Further ignoring this problem can lead to very serious consequences for residents of new areas [11, 12].

References
[1] Ning Q and Tong H 2020 Noise Control Engineering Journal 68(5) 378–388
[2] Salomons E M, Bijsterveld K, Traa A and Ogren M 2014 Noise Control Engineering Journal 62(6) 422–435
[3] Ivanov N I and Butorina M V 2015 Vestnik MGSU 3 136
[4] Mel'cer A V, Borovkov N V and Kuznecova E B 2006 Collection of reports Protection of population from increased noise impacts (St. Petersburg: BSTU «VOENMEH») pp 27–29
[5] Nguyen T L, Morihara T, Yano T and Yokoshima S 2018 Noise Control Engineering Journal 66(6) 459–471
[6] Ahmetzyanov I M, Red'ko A A and Sergeev O E 2006 Collection of reports Protection of population from increased noise impacts (St. Petersburg) pp 168–174
[7] Vishnyakov A N and Kurilenko Y V 2006 Collection of reports Protection of population from increased noise impacts (St. Petersburg) pp 196–202
[8] Butorina M V, Minina N N, Tyurina N V and Anisimov E P 2017 Collection of reports Protection against increased noise and vibration (St. Petersburg: BSTU «VOENMEH») pp 69–78
[9] Butorina M V, Berndt A and Shal' J 2006 Collection of reports Protection of population from increased noise impacts (St. Petersburg: BSTU «VOENMEH») pp 66–76
[10] Engel M S and Zannin P T 2017 Noise Control Engineering Journal 65(6) 590–610
[11] Shubin I L, Grebenkin A M and Grebenkin E V 2017 Building and reconstruction 71(3) 101–106
[12] Salomons E M, Janssen S A and Verhagen L M 2014 Noise Control Engineering Journal 62(6) 449–466