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Assessment of the public health risk from noise pollution of the Saint Petersburg center

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Abstract. The purpose of this study is to assess the risk to public health from exposure to road noise in the historical city center of St. Petersburg., the source of which is automobile (freight, passenger, public) transport. The presented article is devoted to an urgent problem – the assessment of the noise environment and the levels of the emerging risk to the health of the population exposed to traffic noise in dense urban areas. The risk assessment was carried out based on the results of field measurements of noise levels in the zone of influence of traffic flows. The quantitative risk assessment was carried out in accordance with the methodological recommendations of MP 2.1.10.0059-12 «Assessment of public health risk from exposure to traffic noise» and Instructions 2.1.8.10-12-3-2005 «Assessment of the risk to public health from exposure to noise in populated areas». The relevance of the work is confirmed by the fact that motor transport is becoming an increasingly priority source of noise pollution of streets, house territories, residential areas. The analysis of the results of the performed acoustic measurements indicates that the values of the equivalent and maximum sound levels at all four control points exceeded the normative noise exposure levels from 6 to 29.9 dBA. At the same time, the actual values varied from 61.2 dBA to 74.9 dBA for L(A)eq. and from 70.4 to 85.7 L(A)max. The obtained result indicates a significant noise impact of motor transport on the nearest residential area, which can lead to adverse health consequences.

1 Introduction

The growing role of noise as a significant environmental pollutant and its associated adverse health effects are of increasing concern to urban populations and regulators. Noise not only directly affects the auditory system, for example, causing hearing loss and tinnitus due to exposure to high noise levels, but chronic exposure to lower noise levels can also lead to psychological stress and cardiovascular complications.

According to recent estimates by the World Health Organization (WHO), exposure to traffic noise (in addition to air pollution) [1-3]) is estimated to lead to the loss of more than 1.5 million healthy years of life per year in Western Europe, with most of these years

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associated with irritation, cognitive impairment and sleep disorders [4]. The main mechanisms by which noise causes mental stress are associated with elevated levels of stress hormones and blood pressure, which in turn contribute to the development of cerebrovascular diseases such as stroke and hypertension [3]. In addition, exposure to traffic noise is associated with mental health problems and psychological conditions such as depression and anxiety, which further enhances maladaptive coping mechanisms (for example, alcohol and tobacco use) [4, 5]. For 5 years, researchers [6] used a spatial prediction model to estimate noise levels in the living quarters of 5,227 people and studied the relationship between noise levels and common cognitive disorders (including mild neurocognitive disorder (MCI), in which cognitive functions are slightly reduced, and Alzheimer's disease), as well as cognitive indicators and the rate of cognitive decline.

It was found that among these participants, an increase of 10 decibels above the standard (A-normalized) noise level (dBA) was associated with an increased likelihood of MCI and Alzheimer's disease by 36% and 29%, respectively. This noise level has also been associated with a decrease in general cognitive abilities, especially in terms of information processing speed. These results complement existing evidence suggesting that noise exposure may affect the cognitive abilities of older adults and increase the risk of cognitive impairment and dementia. A favorable stay in the city directly depends on the state of the environment, including acoustic pollution [7-9], air pollution [10, 11] and other factors affecting human health. To a large extent, the acoustic pollution of the urban environment is influenced by traffic flow. The accumulation of a large number of motor vehicles, rail transport and industrial activities in a relatively limited area leads to a deterioration in living conditions [12].

2 Materials and methods

Identification of logical and causal relationships between the effects of adverse and dangerous environmental factors and pathological changes in human health, analysis and assessment of the risks of exposure to adverse environmental factors are the main elements of a comprehensive health diagnosis. The assessment of risks to public health helps to solve research and practical problems in the field of hygiene, occupational medicine, toxicology, epidemiology and ecology in order to establish cause-and-effect relationships between the levels of exposure to environmental factors and the state of public health.

The noise level that affects a person is greatly influenced by: the type of car, the quality of the road, the number of lanes, the presence of road intersections, the presence and number of stopping points and other factors.

The following factors directly affect the propagation of sound from traffic flows in space: the distance from highways and railways to residential buildings, the presence of green spaces along highways, urban features, natural and climatic factors [13].

In the course of this work, acoustic measurements of noise from traffic flows in the Moskovsky district of St. Petersburg were carried out; an assessment of compliance of the results with the requirements of sanitary standards was carried out; an assessment of risks to public health was carried out; proposals were prepared for possible reduction of noise from traffic flows in the Moskovsky district of St. Petersburg. noise reduction from traffic flows in the Moskovsky district of St. Petersburg. Measures have been developed to manage urban noise and hazards.

During the research, measurements of the equivalent and maximum noise levels were carried out in accordance with GOST 23337.

Sound level measurements were carried out using an instrumental method using a digital fusion meter and an octave spectrum analyzer 110A of resolution class 1 according to GOST R.53188.1.

Sections of Moskovsky Prospekt in the Central District of St. Petersburg were selected as measurement points, since the street is a road with heavy traffic, as well as adjacent adjacent areas of St. Petersburg. Moskovsky Prospekt includes 6 traffic lanes (3 lanes in each direction of travel) and is characterized by a dense flow of urban, passenger and municipal transport.

High traffic density leads to a significant noise impact on the surrounding area, including the territory of the nearest residential complex [14, 15]. The measurements were carried out at four control points, including one located 2 m from the facade of a residential building facing the noise source (Fig. 1).

Fig. 1. Noise measurement locations

Sound measurements were carried out by the authors in the cold season (February), on a weekday, during the daytime (from 7 to 23 o'clock) and at night time (from 23 to 7 o'clock). The description of the sound measurement points is shown in Table 1.

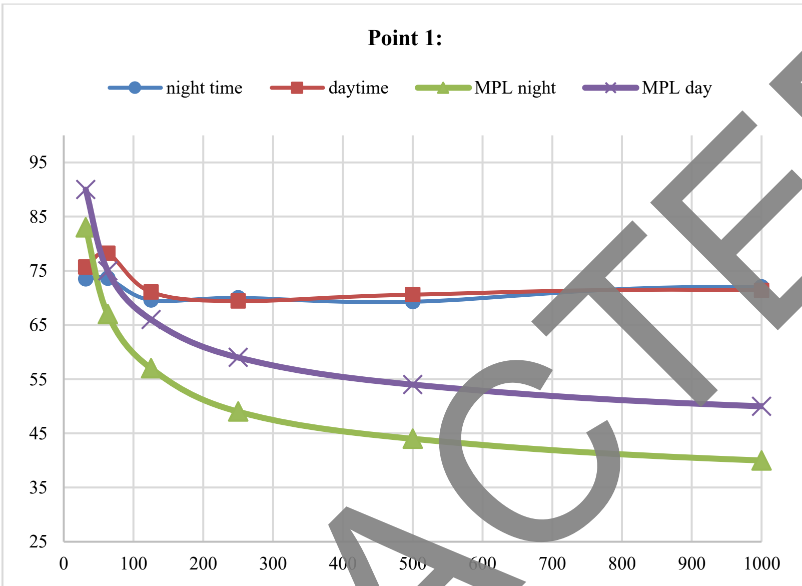
Table 1. The description of the sound measurement points

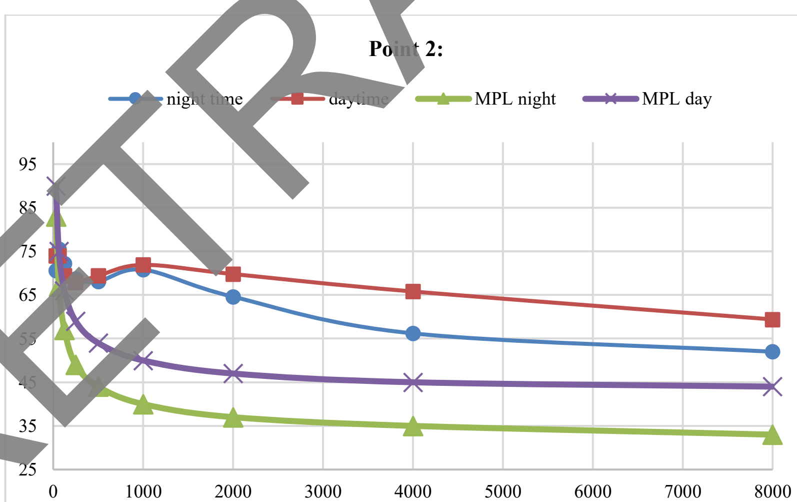
Point number	Description of the point
Point 1	The measuring point is located at 9 Moskovsky Prospekt, University building. (The distance to the noise source is 2 meters)
Point 2	The measuring point is located near the intersection of Moskovsky Prospekt with the Fontanka River embankment in front of a park with green spaces (The distance to the noise source is 2 meters)
Point 3	The measuring point is located at 14 Moskovsky Prospekt, 2 m from the facade of an apartment building. During the measurement, the microphone of the noise meter was located in the direction of the intersection of traffic flows of Moskovsky Prospekt and the Fontanka River embankment. (The distance to the noise source is 35 m)
Point 4	The measuring point is located at the intersection of Moskovsky Prospekt and Sadovaya Street. (The distance to the noise source is 20 m).

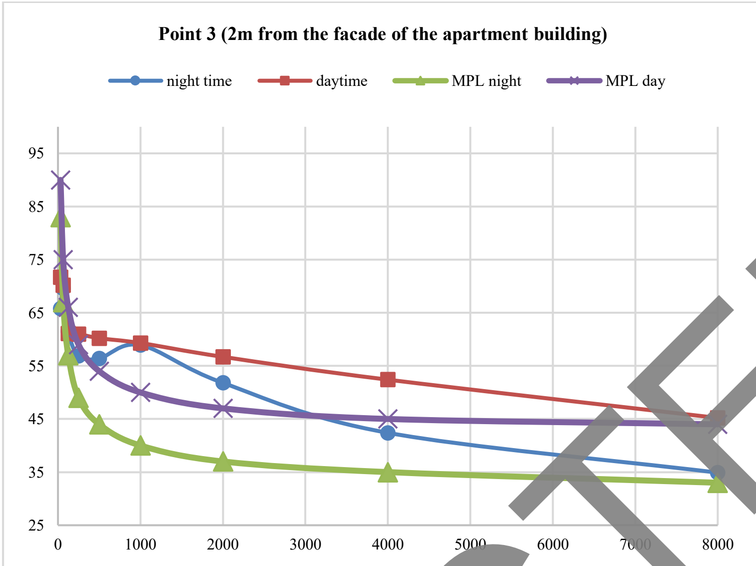
The high volume of car traffic has a significant impact on the noise level in the surrounding area, including the area of nearby residential development. This is evidenced by a survey of a local resident (the tenant of the house next to which the measurements were carried out) regarding their subjective feelings after noise measurements. A local resident reported that he experienced an unpleasant and oppressive feeling from the noise produced by cars.

3 Results

During measurements of the noise level of traffic flows, it was found that the maximum permissible levels (MPL) for day and night were exceeded in almost the entire frequency range (Fig. 2).







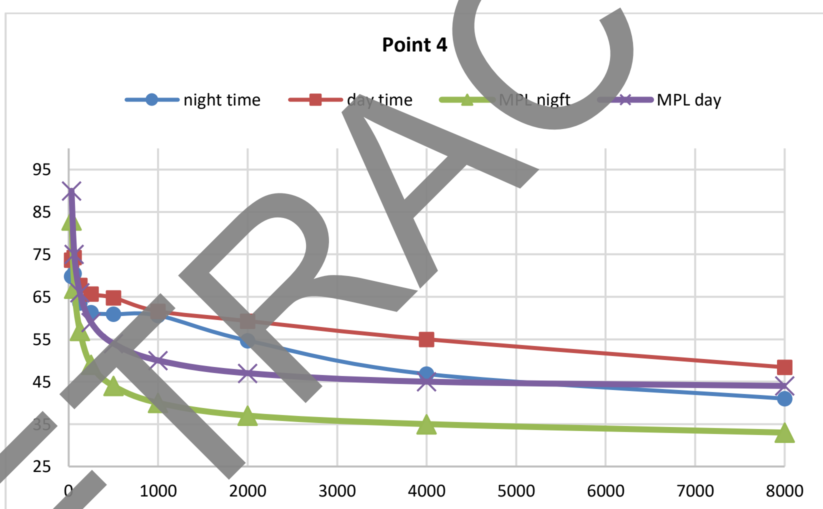


Fig. 2. Graphs of changes in noise levels from vehicles along octave bands at measurement points No.1-4.

According to the requirements of SanPiN 1.2.3685-21 «Sanitary norms and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans», «the maximum permissible noise levels may be increased by 10 dBA in the case of noise generated on the territory of residential buildings by road, two meters from structures surrounding the first level of noise-resistant types of residential buildings overlooking the main streets» [2].

In our case, it is impossible to adopt an amendment of 10 dBA to normalize the permissible noise level in residential buildings, because in a number of apartments at 14 Moskovsky Ave., many windows of living rooms have wooden frames that are not noise-proof (Fig.3).

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The maximum and equivalent sound levels at measurement points No. 1-4 are shown in Table 2.

Table 2. The results of measurements of the equivalent and maximum noise exposure levels

№ measuring points	Daytime (7-23)	Night time (23-7)
	Equivalent sound level, L(A)eq, dBA	
1	74,9	74,8
2	75,7	73,2
3	64,5	61,2
4	67,0	63,9
The maximum permissible level	55	45
	Maximum sound level, L(A)max, dBA	
1	85,7	83,7
2	85,3	84,9
3	73,0	70,4
4	71,8	71,2
The maximum permissible level	70	60

Fig. 3. Wooden window frames on the facade of the building facing Moskovsky Prospekt, measuring point No. 3.

4 Discussion/ Analysis of the results

According to the measurement results, significant exceedances of the maximum permissible noise levels for a residential area were detected at all measurement points, both day and night. The result indicates a significant impact of car noise on the nearest residential area, which can lead to negative health consequences.

Analysis of the results of the acoustic measurements shows that the values of the equivalent and maximum noise levels at all four control points in the cold season exceeded the standard noise exposure levels from 6 to 29.9 dBA. At the same time, the actual values varied from 61.2 dBA to 74.9 dBA for L(A)eq. and from 70.4 to 85.7 L(A)max (fig.4, 5).

At point 3 (directly 2 m from the facade of the apartment building), we can observe the exceedance of the remote control practically over the entire band of measured frequencies.

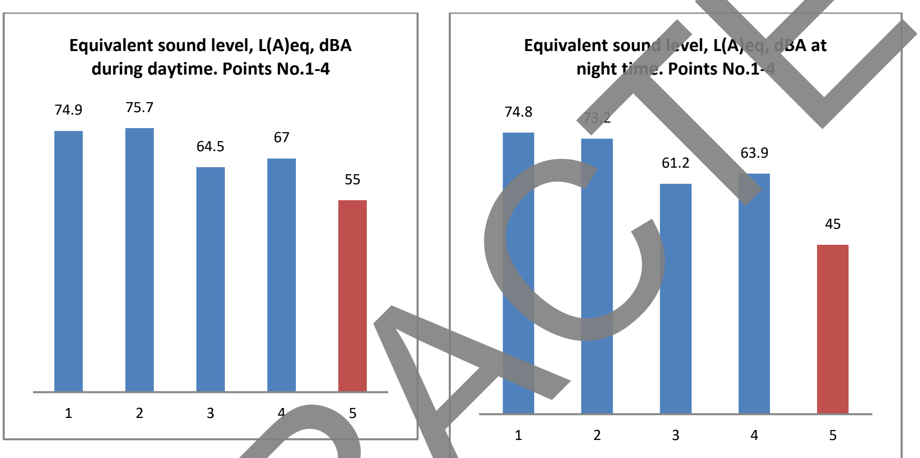

Fig. 4. Measurement of the equivalent sound level L(A)eq. in different time intervals, where 5 is the remote control (MPL)

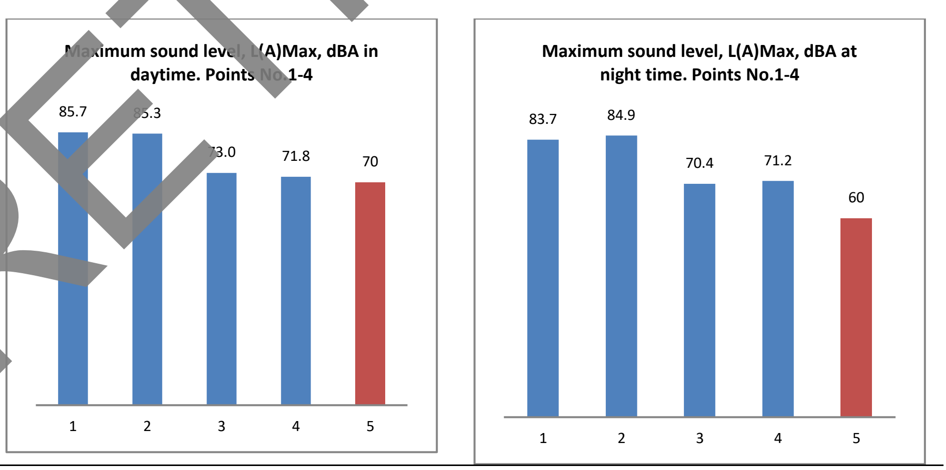

Fig. 5. Measurement of the maximum sound level L(A)max. in different time intervals, where 5 is the remote control (MPL)

The results obtained as a result of acoustic measurements indicate a significant excess of noise pollution, which in the long term can lead to disorders of the nervous and circulatory systems, as well as cause diseases of the ear and mastoid process. The analysis of the measurement results confirmed the need to take noise protection measures to ensure a standard noise level in the historical center of St. Petersburg.

Clause 4.3 of SP 51.13330.2011 «Noise protection» specifies measures to protect the residential area from noise, including a number of points, the requirements of which are practically impossible to implement on the territory of the current historical development. For example, compliance with the size of the sanitary clearance zone of highways and the placement of special noise-resistant buildings along highways; the use of various composite technologies for the assembly of noise-resistant buildings and conventional structures, constructive measures involving the construction of roadside noise shields.

The application of these measures in the area where acoustic measurements were carried out is difficult due to the current historical development, the presence of some buildings of cultural and historical value.

Of the noise protection measures listed in SP 51.13330.2011 "Noise protection", limited options can be used within the framework of the presented work, such as, for example:

- Organizational measures aimed at reducing the movement of freight transport in residential areas and reducing the speed of vehicles when passing through residential, recreational and medical areas. The measurements were carried out in the period after a heavy snowfall, and at that time a large number of municipal snow removal equipment, including dump trucks, were involved on Moskovsky Prospekt.

- Installation of noise-proof windows in buildings located in an area exposed to harmful effects of noise. Not all windows of historical buildings have been replaced with noise-proof glass. It is quite common to observe windows with wooden frames, the sound insulation of which is often unsatisfactory (Fig. 3).

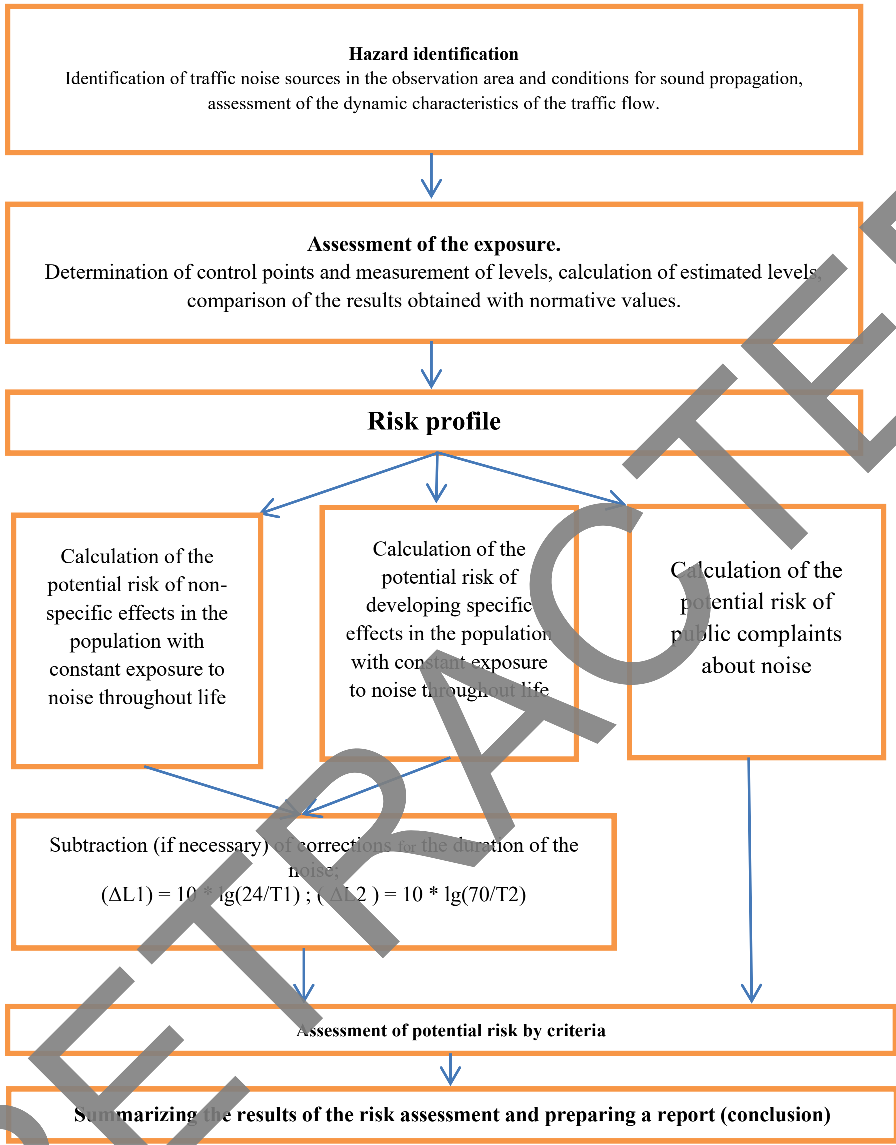

Fig. 6. Algorithm for assessing the potential risk to public health from exposure to motor vehicle noise.

The methodological recommendations of MP 2.1.10.0059-12 were used to calculate the health risk. The calculation was performed for point No. 3, located directly in front of the residential building, with the facade facing the noise sources (Table. 3) according to the algorithm in Figure 6.

Table 3. The calculation was performed for point No. 3, located directly in front of the residential building, with the facade facing the noise sources

	Daytime		Night time	
	L(A)eq, dBA	L(A)max, dBA	L(A)eq, dBA	L(A)max, dBA
2 m from the facade of a residential building	64,5	73,0	61,2	70,4

The L_{den} indicator (equivalent level of weighted average daily noise), which can be determined by equation (1), taking into account daytime and nighttime noise levels, is used as the main unit of effective noise levels in risk assessment:

$$L_{den} = 10lg\frac{1}{24}\left(16 * 10^{\frac{L_{day}}{10}} + 8 * 10^{\frac{L_{night+10}}{10}}\right) \quad (1)$$

where L_{day}=$L_{Aeg,16}$ - equivalent adjusted 16-hour daytime noise level;
L_{night}=$L_{Aeg,8}$ - equivalent adjusted 8-hour night noise level.
According to formula (2), an estimate of the equivalent noise level for any given period can also be performed, and it will be calculated L_{day} and L_{night}:

$$L_{Aeg} = 10lg\frac{\left\{\left[\frac{1}{T}\int_0^T p^2\right]\right\}}{p_0^2} \quad (2)$$

In this formula, it is necessary to determine p^2 - the sound pressure at the observation point, Pa, using the following formulas (3), (4):

$$p = 10^{\frac{L}{20}+lgp_0} \quad (3)$$

$$p^2 = 10^{\frac{L}{10}+lgp_0^2} \quad (4)$$

We find p^2 by the formula (4), where p_0^2 is the initial sound pressure in the air $p_o = 2*10^{-5}$, Pa (reference sound
pressure):

$$p^2day = 10^{\frac{64,5}{10}+lgp_0^2} = 0,00113 \text{ (Pa)}$$

$$p^2night = 10^{\frac{61,2}{10}+lgp_0^2} = 0,00053 \text{ (Pa)}$$

We find L_{day} and L_{night} by the formula (2):

$$L_{day} = 10lg\frac{\left\{\left[\frac{1}{16}\int_0^T p^2\right]\right\}}{p_0^2} = 61,2 \text{ (dBA)}$$

$$L_{night} = 10lg\frac{\left\{\left[\frac{1}{8}\int_0^T p^2\right]\right\}}{p_0^2} = 63,9 \text{ (dBA)}$$

Calculate the parameter L_{den} using the formula (1):

$$L_{den} = 10lg\frac{1}{24}\left(16 * 10^{\frac{61,2}{10}} + 8 * 10^{\frac{63,9+10}{10}}\right) = 69,6 \text{ (dBA)}$$

The measured average equivalent noise level 2 m from the facade of an apartment building – 69.6 dBA exceeds the normalized level by 14.6 dBA, which suggests a negative impact of noise and the need to calculate the potential risk of adverse effects in the population. To calculate the risk of adverse effects in the population, we will use the following equations based on the normal probability distribution of the frequency of effects, taking into account the requirements of MP 2.1.10.0059-12 (Table 3, paragraphs 3.7; 3.8; 3.9):

– Calculation of the potential risk of public complaints about noise:

$$P_{rob} = -6,5027 + 0,0889 * L_{den.eq} \quad (5)$$

– Calculation of the potential risk of non-specific effects in the population with constant exposure to noise throughout life:

$$P_{rob} = -4,5551 + 0,0853 * L_{den.eq} \quad (6)$$

– Calculation of the potential risk of developing specific effects in the population with constant exposure to noise throughout life:

$$P_{rob} = -6,6771 + 0,0704 * L_{den.eq} \quad (7)$$

где: $L_{den.eq}$ – the equivalent level of motor vehicle noise (dBA) in the observation area, calculated according to (1)
Prob – an intermediate coefficient that is associated with risk (Risk) in accordance with the standard normal probability distribution of the frequency of effects.

Equations (6) and (7) reflect the "dependence–response" with constant exposure to noise during the day (24 hours) and throughout a person's life (70 years). If the expected noise exposure lasts less, corrections for the duration of action during the day ΔL_1 (8) and the total exposure period ΔL_2 (9) must be subtracted from the Leq value:

$$\Delta L_1 = 10Lg(24/T_1) \quad (8)$$

$$\Delta L_2 = 10Lg(70/T_2) \quad (9)$$

where T_1 is the average time (hours) of noise action during the day; where T_2 is the total period of exposure (years).

Using the formulas we get:

$$\Delta L_1 = 10Lg\left(\frac{24}{12}\right) = 3,01$$

$$\Delta L_2 = 10Lg\left(\frac{70}{70}\right) = 0$$

In the calculations of the presented work, the corrections ΔL_1 and ΔL_2 are not taken into account, since the effect of an equivalent level of weighted average daily noise on the human body occurs during the day.

$P_{rob} = -6{,}5027 + 0{,}0889 * 69{,}6$ = - 0,3

$P_{rob} = -4{,}5551 + 0{,}0853 * 69{,}6$ = 1,4

$P_{rob} = -6{,}6771 + 0{,}0704 * 69{,}6$ = - 1,8

Using the translation table (Tables 4, 5, 6, 7), we will determine the risks for the relevant items:

Table 4. Normal probability distribution (MP 2.2.10.0059-12)

Prob	Risk	Prob	Risk
-3,0	0,001	0,1	0,540
-2,5	0,006	0,2	0,579
-2,0	0,023	0,3	0,618
-1,9	0,029	0,4	0,655
-1,8	0,036	0,5	0,692
-1,7	0,045	0,6	0,726
-1,6	0,055	0,7	0,758
-1,5	0,067	0,8	0,788
-1,4	0,081	0,9	0,816
-1,3	0,097	1,0	0,841
-1,2	0,115	1,1	0,864
-1,1	0,136	1,2	0,885
-1,0	0,157	1,3	0,903
-0,9	0,184	1,4	0,919
-0,8	0,212	1,5	0,933
-0,7	0,242	1,6	0,945
-0,6	0,274	1,7	0,955
-0,5	0,309	1,8	0,964
-0,4	0,345	1,9	0,971
-0,3	0,382	2,0	0,977
-0,2	0,421	2,5	0,994
-0,1	0,460	3,0	0,999
0,0		0,50	

Table 5. Criteria for assessing the magnitude of the potential risk of public complaints and the development of specific (auditory) effects (MP 2.2.10.0059-12)

The level of risk	%	in fractions of units.
Acceptable	up to 2%	up to 0,02
Satisfactory	2–16%	0,02–0,16
Unsatisfactory	16–50%	0,16–0,50
Dangerous	>50%	>0,50
Extremely dangerous	100%	1

Table 6. Criteria for assessing the magnitude of the potential risk of developing non-specific (non-auditory) effects (MP 2.2.10.0059-12)

The level of risk	**%**	**in fractions of units.**
Acceptable	up to 5%	up to 0,05
Causing concern	5–16%	0,05–0,16
Dangerous	16–50%	0,16–0,50
Extremely dangerous	50–84%	0,50–0,84
Catastrophic	100%	1

Table 7. Types of health disorders of the population living under the influence of traffic noise (MP 2.2.10.0059-12)

Affected organs and systems of health disorders Data on threshold noise levels, dB	Affected organs and systems of health disorders Data on threshold noise levels, dB	Affected organs and systems of health disorders Data on threshold noise levels, dB
The nervous system	Nervousness (nervous tension, irritation)	35
	Sleep disorder	40
	Cognitive impairment	42
	Vegetative-vascular dystonia	60
The circulatory system	The increase in blood pressure is nonspecific, without a diagnosis of hypertension	65
	Hypertensive heart disease	70
	Coronary heart disease	70
	Angina pectoris	70
	Myocardial infarction	70
Diseases of the ear and mastoid process	Tinnitus (subjective)	45
	Conductive and sensorineural hearing loss	80
	Hearing loss caused by noise	80

The result of the risk assessment is presented in table 8:

Table 8. Results of the health risk assessment from noise pollution.

The risk of public complaints	Risk	0,382	Unsatisfactory (high risk of complaints and dissatisfaction of the population)
The risk of developing non-specific effects	Risk	0,919	Catastrophic (Non-specific increase in blood pressure, without diagnosis of hypertension, sleep disorder)
The risk of developing a specific pathology	Risk	0,036	Satisfactory (tinnitus)

The risk characteristic combine data obtained at all previous stages of the study and are designed to obtain quantitative and qualitative risk assessments, identify and analyze the relevance of current public health issues and also the link between health risk assessment and risk management. Recommendations on noise risk management can be made taking into account the assessment scale (Table 9).

Table 9. Evaluation scale (source: methodological recommendations MP 2.1.10.0059-12)

№	The amount of risk	Risk assessment	Management decisions
1	Risk < N	Low risk	Noise load monitoring
2	N < Risk < Risk $_{background}$	Moderate risk	Screening of highways and residential areas, "green" screening, the use of noise-absorbing structures and glazing of residential and public buildings, an expanded monitoring program
3	Risk > Risk $_{background}$	Increased, high risk	Revision of design documentation justifying the size of sanitary gaps/SPZ, resettlement of the population, construction and reconstruction of buildings using special technologies that ensure a high level of their noise protection

5 Conclusion

On the territory of the historical center of St. Petersburg in the area of the intersection of Moskovsky Prospekt and the Fontanka River embankment in the immediate vicinity of the facade of an apartment building, the danger is defined as catastrophic and unsatisfactory, and residents living in the described noise zone have a high risk of developing diseases, Respectively, it is necessary, at least, the use of noise-absorbing structures, an expanded monitoring program, and also, the reconstruction of buildings using special technologies that provide a high level of noise protection.

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