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EVOLUTION OF THE HEALTH DISORDERS RISK IN THE POPULATION UNDER DEVELOPMENT OF URBANIZED TERRITORIES

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***Abstract**: In the present study, an approach has been tested for assessing and mapping the risk levels caused by the impact of the noise factor in urban development on the example of urbanized areas of a large city. The approach is based on an acoustic modeling algorithm associated with work in geographic information systems (hereinafter referred to as GIS) for the tasks of hygienic regulation and health risk assessment of the population living in dense urban areas. The paper describes the identification and integration of a set of initial data on the noise factor of exposure with the subsequent construction of a computational model. The results obtained are supplemented with methodological approaches to assess the health risk of the population from the impact of traffic noise in accordance with the approved methodological recommendations for the impact of this factor.*

Risk levels are calculated without changes in the urban planning situation in the study area with the duration of residence of the exposed population of 20, 30, 40 years. In addition, predictive calculations of changes in risk levels for a period of 20, 30, 40 years in the context of a construction project were performed. Risk calculations were carried out at 49210 calculated points located in 38 planes, including at a height of 1.5 m at the level of human breathing in the area of residential buildings, corresponding to each computational grid, to build a volumetric (3D) model. The volumetric model is built to assess the living conditions of the exposed population, depending on the floor of residence. A moderate risk before the implementation of a construction project is formed up to a maximum of 13, 21, 23 meters in living conditions for 20, 30, 40 years, respectively, while after the implementation of the project, a moderate risk reaches a maximum height of 21, 39, 51 meters in conditions of a similar exposure duration (20, 30, 40 years old). A high risk in both cases is observed at a height of 1.5 - 3 meters above ground level only during 40 years of living in the area of this exposure, which is due to the previously close located highways. Thus, under dense urban development, it is optimal to live on the middle floors (7-8 floors) and above, in conditions of chronic exposure to the noise factor.

***Keywords:** geographic information systems, acoustic calculation, noise risk assessment*

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1. INTRODUCTION

As a result of the economic activities of legal entities and individual entrepreneurs on the territory of large industrial cities, significant chemical, noise and electromagnetic pollution is formed, harming the health of the population living in the study area. At the same time, the deterioration of living conditions of the population is consistently recorded in the reports of state authorities, such as in the State report „On the state of sanitary and epidemiological well-being of the population in the Russian Federation in 2019", formed by the Federal Service of Rospotrebnadzor in the Russian Federation (hereinafter RF). This report reflects the situation to ensure the sanitary and epidemiological well-being of the population on the territory of the Russian Federation in all areas [1]

Modern approaches make it possible to assess the impact of each of the factors on the health of the population, taking into account the risk criteria. However, a deep study of an individual factor, namely noise exposure, is a complex information and analytical system that requires the implementation of effective methods of accumulation, search, science-intensive processing information for decision-making, maintaining information arrays that reflect the spatial distribution and dynamics of the noise factor affecting health indicators with reference to a single digital topographic basis. This problem is confirmed by the share of complaints from the population about the impact of physical factors, the prevailing majority of which are related to the noise factor (66.8%) [1,2].

The relevance of this study is determined by the urgent need to assess the impact of noise exposure on human health.

This study aims at proving the approaches for calculating and mapping the levels of noise load and levels of formed risk by mapping and visualizing the current and future situation according to the criteria of public health risk considering chronic exposure.

2. MATERIALS AND METHODS

The work on the dynamic assessment of the population's noise exposure was carried out on the site of a promising residential development in a large city of Russia. The assessment was

carried out at the stage of design study of a possible change in the acoustic situation in an urban environment. At the stage of assessing the current situation and the period of implementation of the construction project, the determined exposure levels are of a practical nature for the executive authorities making decisions and for informing the public about their living conditions.

One of the central microdistricts of the city of Perm in the Sverdlovsk region - the Krasnye Kazarmy microdistrict was chosen as the object of the study. The microdistrict is a plot of 30 hectares intended for quarterly development of residential buildings and infrastructure of variable number of storeys: from 8-9 floors (3 and 2 houses, respectively), up to 12-14 floors (5 and 1 houses, respectively) and up to 19-25 floors (2 and 13 houses, respectively). As the infrastructure of the quarter, a shopping and entertainment center (SEC) with a height of 6 floors and a school with a height of 3 floors are designed.

In addition, in the projected development of the quarter, it is planned to open 3 new streets (Wilhelm de Gennin St., Vasily Tatishchev St., Karl Moderakh St.) and 12 new driveways and roads.

As part of the study, databases on stationary and mobile sources of noise in the study area of Perm have been accumulated and updated. The main criteria influencing the propagation of noise impact and participating in the processes of sound insulation and sound absorption (taking into account capital construction objects, natural and artificial barriers) have been determined. The collected data on noise sources made it possible to establish the territorial distribution of sources on the ground, exposure parameters, non-simultaneous operation and other factors affecting the level of noise exposure.

The study used a database of 800 stationary and 2000 mobile noise sources of enterprises in Perm. Accounting for stationary and mobile noise sources was carried out according to the developed identification algorithm [3].

Fig.1: Layout of residential buildings within the boundaries of the residential quarter „Arsenal"

Acoustic calculations were performed using modern software that describes the laws of sound wave propagation in the area and approved within the framework of the current legal assessment of physical factors of influence. In particular, the research used the software product „Ecolog-SHUM" (by „Integral"), which implements GOST 31295.1-2005 (ISO 9613-1: 1993) „Noise. Attenuation of sound when spreading over terrain. Part 1. Calculation of sound absorption by the atmosphere" [4] and SP 51.13330.2011 Protection against noise. Updated version of SNiP 23-03-2003 (with Amendment No. 1) [5], and approved by the Federal Service for Supervision of Consumer Rights Protection and Human Welfare.

The exposure assessment was carried out on a regular grid within the boundaries of the calculated rectangle with a size of 0.9 * 0.9 km. The regular grid included 1295 calculated points at a height of 1.5 m at the level of a person's breathing in the area where residential buildings are located. In total, the exposure was determined at 49210 design points located in 38 planes corresponding to each computational grid to build a volumetric (3D) model.

Particular attention was paid to the elevation marks of typical buildings of 5-storey buildings (calculated at 15 meters), 9-storey buildings (calculated at 27 meters), 14-storey buildings (43 meters), 20-storey (61 meters), 25-storey (at 75 meters). For clarity and orderliness of building a picture of noise impact, acoustic calculations were carried out every 2 meters.

The assessment of the public health risk by the noise factor for the population living for a long time in the adjacent territory and planning to settle in the project area was carried out using data from model acoustic calculations. Based on the results of the risk assessment, a quantitative and qualitative characteristic of the risk of the study area was obtained. Based on the results, significant existing problems for the health of the population were revealed, and possible deterioration of the situation for the tasks of managing the generated risk. The algorithm for calculating the risk is carried out in accordance with the Methodological Recommendations 2.1.10.0059-12 „Assessment of the public health risk from the impact of traffic noise" [6].

The risk calculation was carried out sequentially with the implementation of the following stages:
- generalization of the results of hazard identification, exposure assessment and modeling of „exposure - response probability" relationships;
- calculation of the risk of effects during noise exposure;
- health risk analysis;
- identification and analysis of risk assessment uncertainties.

The calculation of the risk of individual effects during acoustic exposure is based on the solution of a system of recurrent equations incorporated in the method used. As part of the study, in the numerical solution of the system of equations, predictive data were used that characterize the time distribution of the exposure of the factor taken into account for the entire calculation period.

The basis for the study was a vector map of the city of Perm with a set of electronic layers in *.shp format containing spatial objects of the city in electronic form with accompanying

attributive information. For mapping and assessing the scale of the planned construction, the results of design decisions on the placement of capital construction objects in the study area were used, which was the starting point for calculating the noise exposure and the risk to public health generated by it.

Each group of data on the sources of noise exposure, shielding objects and other elements involved in acoustic modeling was characterized by attributive data about the object of the vector map of the study area. The attributive data on the objects of modeling contained information on the parametric and acoustic characteristics of noise sources, on the elevations of the registered buildings and structures of the city, the parameters of calculated points and sites, and other information necessary to establish the location and characteristics of the object in question in the study area.

Geographic information systems (hereinafter GIS) were used in the form of the ArcGIS 9.3 program for preparatory work and assessment of the spread of noise on the ground with subsequent visualization. The content (attributive) part of the fields of the used GIS was prepared as per the used filling fields in the program „Ecolog-Shum" and reporting tables of the generated results.

The transformation of the results of acoustic calculations and their visualization were carried out using the additional module GIS-Ekograf as part of the Ecolog-SHUM program and the ArcScene module as part of the ArcGIS 9.3 program. In particular, within the framework of exposure assessment and risk calculation, 2D and 3D models of the formation of noise exposure and zones of acoustic discomfort based on hygienic criteria and criteria of risk to public health were used as mapping of the results.

The final stage of the work was the display of the results of acoustic calculations and the formation of maps of the territory with an assessment of the existing negative impact on the population according to the criteria of risk to public health and an assessment of the near future.

The generated maps on the propagation of noise in the study area made it possible to assess the degree and zones of influence of acoustic exposure.

Mapping the results of risk assessment made it possible to visually highlight areas of various risks, primarily moderate and high risks, requiring immediate management decisions to minimize the risk to correct the situation [7].

3. HYGIENIC ASSESSMENT OF THE RESULTS OF ACOUSTIC CALCULATIONS USING GIS

3.1. Analysis of the results of acoustic calculations

The analysis of the obtained results of acoustic calculations showed that within the boundaries of the study area under consideration, noise levels are formed above the hygienic standards (more than 55 dBA for daytime and more than 45 dBA for night time), due to the location of adjacent highways (Fig. 2).

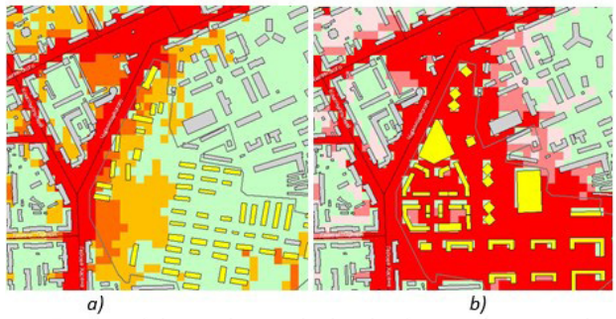


Fig. 2: Zoning of the study area by levels of equivalent noise level (a - before construction, b - after construction)

Thus, the results of acoustic calculations in the surface layer of 1.5 meters at the level of human audibility showed that the situation changes significantly after the implementation of the project due to the emergence of additional noise sources (highways). Comparative assessment of the zoning of the territory by the levels of equivalent noise depending on the height of the estimated estimate for typical heights of residential buildings (15 meters for 5-storey buildings, 27 meters for 9-storey buildings, 43 meters for 14-storey buildings, 61 meters for 20-storey houses, 75 meters - for 25-storey houses) is shown in Figs. 3 and 4.

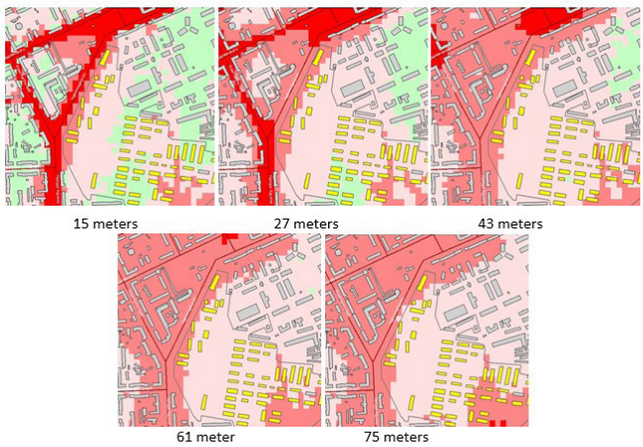


Fig. 3: Zoning of the study area according to the levels of the equivalent noise level at different heights before the construction of a residential complex

Assessment of the acoustic situation after the implementation of construction (Fig. 4) shows that after 27-30 meters there is a decrease in the zone of acoustic discomfort.

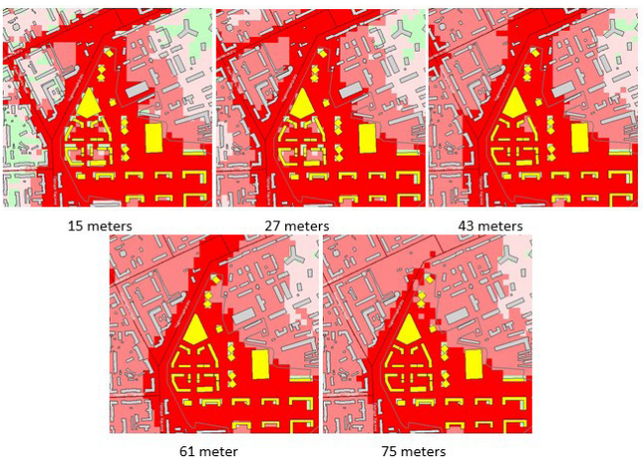


Fig. 4: Zoning of the study area according to the levels of the equivalent noise level at different heights after the construction of a residential complex

The obtained results of acoustic calculations reflect the violation of hygienic standards in terms of noise load levels, but do not characterize possible health disorders of the population associated with chronic exposure to the noise factor in terms of public health risk.

3.2. Calculation and zoning of public health risk

According to the results of the acoustic calculations, it was established that the levels of risk formed at heights of 1.5 meters and 15 meters to the existing position are formed unacceptable health risks only along the central highways, while the results of the construction of residential complexes, the resulting moderate risks are typical for the territory of the microdistrict with the subsequent formation of high risks after 40 years of living in the considered territory.

Fig. 5: Zoning of the study area by risk levels at a height of 1.5 meters before the planned construction of a residential complex with a duration of residence of 20, 30, 40 years

Fig. 6: Zoning of the study area by risk levels at a height of 1.5 meters after the planned construction of a residential complex with a duration of residence of 20, 30, 40 years

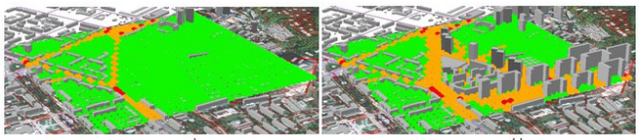


Fig. 7: 3D model of zoning of the study area by risk levels at a height of 1.5 meters with a duration of residence of 40 years (a - before construction, b - after construction)

The results obtained indicate that a moderate risk before the implementation of a construction project is formed at the maximum heights of 13, 21, 23 meters in the conditions of population living for 20, 30, 40 years of chronic exposure. While the period after the construction of a residential complex, a moderate risk reaches the maximum height of 21, 39, 51 meters under conditions of a similar exposure duration (20, 30, 40 years). A high risk in both cases is observed at a height of 1.5 - 3 meters above ground level only during 40 years of living in the conditions of this exposure, which is due to closely located highways. Extremely high risk levels are not formed throughout the considered assessment period (20-40 years).

Height	Highest equivalent noise levels	Before construction			Highest equivalent noise levels	After construction		
		20 years	30 years	40 years		20 years	30 years	40 years
1	2	3	4	5	6	7	8	9
1.5	73.10	0.139240	0.263414	0.458430	73.10	0.139240	0.263414	0.458430
3	69.90	0.109432	0.205680	0.355904	69.90	0.109432	0.205680	0.355904
5	67.80	0.089734	0.167372	0.287562	67.80	0.089734	0.167372	0.287562
7	66.60	0.078429	0.145331	0.248130	66.70	0.079373	0.147172	0.251427
9	65.60	0.068982	0.126879	0.215058	66.20	0.074653	0.137959	0.234925
11	64.80	0.061406	0.112063	0.188461	65.70	0.069928	0.128728	0.218374
13	64.00	0.053815	0.097197	0.161740	65.30	0.066143	0.121329	0.205099
15	63.30	0.047159	0.084149	0.138257	65.00	0.063302	0.115771	0.195122
17	62.70	0.041445	0.072936	0.118052	64.60	0.059510	0.108351	0.181793
19	62.20	0.036676	0.063569	0.101161	64.20	0.055714	0.100918	0.168432
21	61.60	0.030945	0.052305	0.080827	63.80	0.051914	0.093473	0.155040
23	61.10	0.026162	0.042896	0.063945	63.50	0.049062	0.087881	0.144976
25	60.60	0.021374	0.033697	0.048560	63.20	0.046207	0.082282	0.134894
27	60.20	0.017856	0.027821	0.038918	62.90	0.043350	0.076677	0.124795
29	59.80	0.016254	0.025205	0.034751	62.70	0.041445	0.072936	0.118052
31	59.50	0.015885	0.024632	0.033957	62.50	0.039538	0.069191	0.111301
33	58.90	0.015147	0.023483	0.032367	62.20	0.036676	0.063569	0.101161
35	58.60	0.014778	0.022908	0.031572	62.00	0.034766	0.059818	0.094391
37	58.30	0.014408	0.022333	0.030776	61.80	0.032856	0.056063	0.087613
39	58.00	0.014039	0.021758	0.029980	61.60	0.030945	0.052305	0.080827
41	57.70	0.013669	0.021183	0.029183	61.40	0.029033	0.048544	0.074033
43	57.50	0.013423	0.020799	0.028651	61.30	0.028076	0.046662	0.070633
45	57.30	0.013177	0.020415	0.028119	61.10	0.026162	0.042896	0.063945
47	57.10	0.012930	0.020031	0.027587	61.00	0.025205	0.041012	0.060691
49	56.60	0.012314	0.019070	0.026256	60.90	0.024248	0.039127	0.057511
51	56.30	0.011944	0.018494	0.025457	60.80	0.023290	0.037253	0.054416
53	56.20	0.011820	0.018301	0.025190	60.60	0.021374	0.033697	0.048560
55	55.90	0.011450	0.017724	0.024390	60.50	0.020415	0.032043	0.045839
57	55.60	0.011080	0.017147	0.023590	60.40	0.019479	0.030497	0.043300
59	55.50	0.010956	0.016955	0.023323	60.30	0.018620	0.029080	0.040977
61	55.20	0.010586	0.016377	0.022522	60.30	0.018620	0.029080	0.040977
63	55.10	0.010462	0.016184	0.022254	60.00	0.016710	0.025938	0.035869
65	55.10	0.010462	0.016184	0.022254	59.90	0.016392	0.025422	0.035057
67	55.10	0.010462	0.016184	0.022254	59.90	0.016392	0.025422	0.035057
69	55.10	0.010462	0.016184	0.022254	59.80	0.016254	0.025205	0.034751
71	55.10	0.010462	0.016184	0.022254	59.60	0.016008	0.024823	0.034222
73	55.10	0.010462	0.016184	0.022254	59.60	0.016008	0.024823	0.034222
75	55.10	0.010462	0.016184	0.022254	59.50	0.015885	0.024632	0.033957

Tab. 1: Risk levels of health disorders formed in the study area, in the conditions of population living in this area for 20, 30, 40 years in urban conditions before and after the construction of a residential complex

Thus, in conditions of dense urban development, it is optimal to live on the middle floors (7-8 floors) and above, in conditions of chronic exposure to the noise factor.

The data obtained indicate that zones of acoustic silence are most often formed inside courtyards due to sound insulation and shielding by buildings and structures along the perimeter of the living area.

Based on the simulation results, zones and heights of violation of the established hygienic standards were identified in terms of noise levels and risk criteria. These results are simply unacceptable when placing new residential buildings, and do not ensure the citizens' right to a favorable living environment.

The results of three-dimensional modeling fully reflect the picture of the distribution of traffic noise levels in dense urban development. The results obtained clearly demonstrate the nature of the propagation of sound waves along the height under the conditions of a changing urban planning situation with the development of new territories.

The use of 3D models makes it possible to fully assess the existing situation and make a forecast of the situation, taking into account the chronic exposure formed in the conditions of urban development. The results obtained and the described approaches are promising in connection with the growing traffic of vehicles and the compaction of urban development in urbanized areas.

4. CONCLUSION

Noise exposure assessment is a key tool in identifying possible health problems associated with exposure to noise. The reliability and accuracy of establishing the noise exposure fully affect the characteristics of the formed risk in the places of residence of the population.

The results of the hygienic assessment showed the presence of exceeding the hygienic standards for the noise level in some areas of the study area by more than 70 dBA, with the set MPL = 55 dBA for the daytime. This fact is due to the proximity of the computational domain to the adjacent highways characterized by high traffic noise.

The results of the risk assessment showed that in the living conditions today and in the near future (20 - 40 years), moderate and high levels of risk of health disorders under the influence of noise are formed.

The obtained results of risk assessment of acoustic exposure levels indicate the need to develop short-term and long-term measures to manage the risk to public health. In the current situation, the development of the following measures seems to be optimal;

- improving the transport scheme, reducing the number of cars allowed in the city center, improving the public transport system, modernizing interchanges, crossings, parking lots;
- ensuring non-stop traffic by creating a „green wave“ and observing the speed limit for vehicles;
- noise protection glazing of residential buildings for the lower floors of buildings (the effect reaches 25-27 dBA);
- protection by distance (removal of buildings from the roadway) and the use of green spaces (the effect reaches 3-4 dBA).

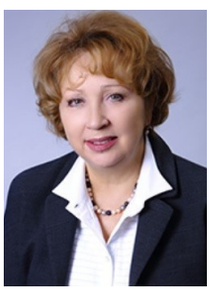
The obtained results of acoustic calculations, hygienic assessment and risk assessment are recommended to be used for the following purposes:

- to be sent to specially authorized bodies that monitor and control the state of the environment;
- to inform the population about the state of noise pollution in the territory of residence;
- to make management decisions and develop action plans to reduce the risk to public health.

The application of methodological approaches for calculating and mapping the levels of noise load and levels of the generated risk by constructing and visualizing (3D) the acoustic situation is a unique and promising assessment tool. Together with the risk assessment methodology, the proposed approaches make it possible to carry out a long-term forecast of the acoustic situation and to ensure the sanitary and epidemiological well-being of the urban population according to the criteria of public health risk, taking into account chronic exposure.

REFERENCES

[1] State report „On the state of sanitary and epidemiological well-being of the population in the Russian Federation in 2019" - URL: https://www.rospotrebnadzor.ru/documents/details.php?ELEMENT_ID=14933 (date of treatment 25/01/2021);
[2] Onishchenko, G.G., Zaitseva, N.V., May, I.V., Shur, P.Z., Popova, A.Yu., Alekseev, V.B., Dolgikh, O.V., Zemlyanova, M.A., Lebedeva-Nesevrya, N.A., Trusov, P.V., Nurislamova, T.V., Ulanova, T.S., Ustinova, O.Yu., Andreeva, E.E., Vlasova, E.M., Goleva, O.I., Kiryanov, D.A., Klein, S.V., Luzhetsky, K.P., Maklalova, O.A. et al.: Health risk analysis in the strategy of state social and economical development. Russian Academy of Sciences The Federal Service for Supervision in the Sphere of Consumer Rights and Individual Welfare Protection Federal Budget Science Institution Federal Research Center of Medical-Preventive Technologies of Public Health Risk Management. Moscow - Perm, 2014
[3] Koshurnikov, D.N.: Algorithm for the formation of a noise map of the city // Healthcare of the Russian Federation. No. 5. p. 62 - 63. 2011
[4] GOST 31295.1-2005 (ISO 9613-1: 1993) Noise. Attenuation of sound when spreading over terrain. Part 1. Calculation of sound absorption by the atmosphere
[5] SP 51.13330.2011 Protection against noise. Updated edition of SNiP 23-03-2003 (with Amendment No. 1)
[6] MR 2.1.10.0059-12 „Assessment of the public health risk from the impact of traffic noise". Guidelines. Moscow: Federal Center for Hygiene and Epidemiology of Rospotrebnadzor, 2012.40 p
[7] Kleyn, S.V., Koshurnikov, D.N.: Assessment of noise exposure and related health risk of the population living in the airport area. News of the Samara Scientific Center of the Russian Academy of Sciences, vol.15, no. 3-6, pp. 1806–1812. 2013



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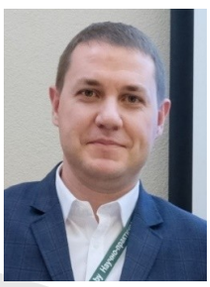

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