Assessment of engineering equipment noise impact of agricultural enterprise on the adjacent residential building

L A Tikhomirov¹, N E Schurova¹, I E Tsukernikov¹,² and T O Nevenchannaya¹,²

¹Research Institute of Building Physics, 127238, Moscow, Russia
²Moscow Polytechnic University, Press and Media Industry Higher School, Moscow, 127550, Russia

Corresponding author: niisf@mail.ru

Abstract. A significant source of increased noise in cities is the engineering and technological equipment of enterprises located in immediate vicinity of standardized objects. The expected noise levels from technological and ventilation equipment of an agricultural enterprise located in the city are estimated. A computer model of the territory under consideration is built using the software package “ARM Acoustics”. As the initial data, the results of field measurements were used. The calculation of the expected noise levels near the facades of residential buildings showed the excess of regulatory levels. It is shown the necessity to install noise screens not only near equipment located on the ground, but also near equipment installed on the roof of the industrial building. The calculation was carried out taking into account the location of the U-shaped screens, which provided effective protection against noise. To illustrate the effect obtained, maps of the spatial distribution of noise are constructed.

1. Introduction

Despite the fact that the main source of noise in cities is traffic noise, often exceeding permissible noise levels in residential areas and in standardized premises can be caused by the work of engineering and technological equipment of enterprises located in the neighborhood [1-4]. In many cases, the operating mode of such equipment involves functioning both in the daytime and at night, and the location in tight urban areas along with the features of the location and design significantly reduce the choice of methods to protect against noise.

In this paper, we estimate the acoustic impact from the equipment of an agricultural enterprise, and the possibility of reducing noise from this equipment.

The facility is located in Moscow in the immediate vicinity of the Kashirskoye highway, and it has a negative effect on residential area situated on the other side of the highway at a distance of 170 - 250 m. Residential area consists of multi-apartment residential buildings with a height of 12 - 25 floors.

The main sources of noise are cluster consisting of five cooling towers, four chillers installed on the ground and 2 single chillers and cooling towers located on the roof of the facility, as well as input ventilation units on the roof. All equipment operates around the clock.

To predict noise exposure in both cases, it is necessary to calculate the expected sound pressure levels of 2 m from the facades of residential buildings at night (from 23 to 7 hours) and at day (from 7
to 23 hours) periods in accordance with the rules of noise standardization according to Russian sanitary rules [5].

2. Forecasting models and methods

To perform acoustic calculations and construct noise maps, we used the ARM “Acoustics” software package version 3.2.7, developed by the Russian company Tekhnoproekt LLC (St. Petersburg), which implements ISO 9613-2:1996 “Noise. Attenuation of sound during propagation outdoors. Part 2. General method of calculation” as a calculation method, considering the technological equipment as point sound sources. A study previously conducted by the NIISF RAASN employees showed high accuracy of the calculations performed by this software product [6, 7].

Noise data of engineering equipment as the time-averaged sound pressure levels in 1/1 octave frequency bands as well as the maximum $L_{A_{max}}$ and time-averaged $L_{A_{eq}}$ A-weighted sound pressure levels were measured at a distance of 1 m from the surfaces of sound sources in accordance with the recommendations of Russian and International standardization documents in accordance with international approach [8, 9] under operating conditions when a maximum noise was emitted by each type of equipment. The noise data of sound sources are presented in table 1.

| №  | Name of sources                      | Sound pressure level, dB, in 1/1 octave band with central frequency, Hz | $L_{A_{eq}}$ | $L_{A_{max}}$ |
|----|--------------------------------------|------------------------------------------------------------------------|--------------|--------------|
| 1  | Compressor in the building            | 33.8 40.6 53.0 61.6 70.4 70.8 70.1 72.5 62.5                         | 77.3         | 77.8         |
| 2  | Cooling tower on the ground           | 27.4 51.5 56.1 71.0 73.6 77.1 69.5 56.0 44.3                         | 79.7         | 80.5         |
| 3  | Input ventilation on the roof         | 34.3 46.6 54.3 62.1 60.1 63.9 61.2 56.1 47.6                         | 68.5         | 70.1         |
| 4  | Cooling tower on the roof             | 33.7 41.6 50.1 56.4 66.1 69.6 58.7 45.9 38.9                         | 71.5         | 73.4         |
| 5  | Compressor on the roof                | 31.2 40.5 47.1 65.9 63.5 62.5 57.9 51.3 39.6                         | 69.3         | 70.5         |
| 6  | Cooling towers on the roof            | 31.0 47.9 62.5 69.5 75.7 75.6 71.1 62.3 46.1                         | 79.9         | 80.8         |
| 7  | Chillers on the roof                  | 92.9 96.0 97.0 95.8 90.3 87.2 81.6 73.3 63.3                         | 92.7         | -            |
| 8  | Chiller on the roof                   | 69.5 71.8 71.7 64.9 59.4 58.5 53.1 47.3 42.1                         | 63.4         | -            |
| 9  | Input ventilation on the roof         | 81.4 71.1 64.1 64.7 62.0 62.3 62.0 69.7 76.0                         | 77.4         | -            |

The layout of buildings relative to sound sources and the considered calculation points (CP) are shown in Fig.1. Six calculation points located near the residential area were selected. The calculation was performed at the level of the first floor at a height of 1.5 m, the fifth floor at a height of 16.5 m and the last floor at a height of 34.5 m, 2 m from the facade of buildings.

The locations of noise barriers designed in the calculation are shown in Fig. 2.

3. Research results and analysis

The calculation showed that in the daytime in the immediate vicinity of residential buildings there are no excesses of permissible time-averaged and maximum noise levels. During the night period, excesses at the height of the first floor are observed near the facades of residential buildings at calculation points CP 3 and CP 6. With an increase in height, excesses occur at all points. The maximum excess at the level of the first floor is 3.6 dB, at the level of the 5th floor – 6.4 dB, at the height of the last floor it reaches 7.3 dB.
In order to protect from noise of the technological equipment, as one of the measures described in [1, 10], noise barriers of 6 m high were designed [11], located along the perimeter of the equipment installed on the ground. To reduce the overall height of the barriers, they are designed with a visor of 0.5 m wide, located at an angle of 45°. As a result, the equivalent barrier height is equal to 7.5 m. Such arrangement of the barriers prevented exceeding permissible levels at the height of the first floor, as well as reducing excesses on higher floors to 3.3 and 3.5 dB, respectively.
To fully meet the requirements of sanitary norms, the option of noise barriers of a U-shape 4 m high near the equipment on the roof of the facility was calculated. This form of the barrier was chosen not only for acoustic reasons, but also because of the peculiarities of the communications on the roof of the building, and also because the U-shaped screen is self-supporting and allows a less complex foundation [12-14]. Such screens should be located near each sound source on the roof.

The results of the predictive calculation of the expected equivalent noise levels for the night period before and after installation of the screens are presented in the form of noise maps [15] for the first, fifth and last floors in Fig. 3. The calculation confirmed that the use of noise barriers near the equipment both on the ground and on the roof of the enterprise allows to completely eliminate negative acoustic effects on nearby residential buildings, both in the daytime and at night.

![Noise maps before and after installation of barriers.](image_url)

**Figure 3.** Noise maps before and after installation of barriers.
4. Conclusions
For the development of measures to reduce noise, a predictive assessment is necessary. At the same time, when equipment is located at different heights, exceeding may not be distributed evenly over the height, therefore, to effectively protect residential buildings from the noise of technological equipment, the need to screen all the noise sources of different heights should be assessed.

When performing a predictive assessment and developing noise protection projects, it is necessary to perform acoustic calculations of noise levels in a residential area using certified software products that meet the requirements of Russian standards.

References
[1] Crocker M J 2007 Industrial and Machine Element Noise and Vibration Sources – Prediction and Control. Handbook of noise and vibration control Part VII (John Wiley & Sones, Inc., Hoboken, New Jersey, USA) 829-1010
[2] Łukasik Z 2016 Emission of acoustic sources of noise in the industrial plants International Journal of Engineering Research and General Science
[3] CasasW J P, Cordeiro E P, Mello T C and Zannin P H T 2014 Noise mapping as a tool for controlling industrial noise pollution Journal of Scientific and Industrial Research
[4] Tsukernikov I E, Tikhomirov L A and Nevenchannaya T O 2020 Projected Multifunctional Hotel Complex Noise Level Prediction from Railway Trains Passing (JSC "Russian Railways“ Connecting Branch Section) with Sound Insulation Measures Development IOP Conference Series: Materials Science and Engineering
[5] Tsukernikov I E, Shubin I L, Ivanov N I and Nevenchannaya T O 2015 Features of Railway Noise Rationing and Assessment in Housing Estate Territory in Russia Procedia Engineering 117 362 – 367
[6] Tsukernikov I and Tikhomirov L 2013 Comparison of results of road noise calculation in a residential area of Moscow obtained using three software tools. Protection from excessive noise and vibration St. Petersburg: Proceedings of the IV national scientific-practical conference with international participation, BGTU 409-419
[7] Tsukernikov I, Shubin I, Tikhomirov L and Nevenchannaya T 2015 Software quality testing for calculation of outdoor noise Maastricht: Proceedings of the 10-th European Congress on Noise Control Euronoise
[8] Tsukernikov I E, Shubin I L and Nevenchannaya T O 2018 Russian Regulatory and Technical Documents on Noise Protection Design IOP Conference Series: Materials Science and Engineering 463 022084 doi:10.1088/1757-899X/463/2/022084
[9] Lee H P, Wang Z and Lim K M 2017 Assessment of noise from equipment and processes at construction sites Building Acoustics
[10] Semin S and Tupov V 2012 Comparison of noise control measures subject to type of used equipment Lithuania: Proceedings of The 19th International Congress on Sound and Vibration
[11] Kotzen B and English C 2009 Environmental noise barriers. A guide to their acoustic and visual design 2nd (New York: Tailor & Francis) 257 p
[12] Voropayev S I, Ovenden N C, Fernando H J S and Donovan P R 2017 Finding optimal geometries for noise barrier tops using scaled experiments The Journal of the Acoustical Society of America
[13] Semin S A, Tupov V B, Taratornin A A and Rozanov D A 2017 Noise Barriers for Power-Plant Equipment Power Technology and Engineering
[14] Kralov I 2017 New solution for transport and industrial noise protection through reflective noise barriers MATEC Web of Conferences
[15] Miguel A 2016 Occupational Noise Mapping in an Industrial Environment OSH 2016: International Symposium on Occupational Safety and Hygiene