Acoustic Treatment Solution of the Technical Room in Water Pumping Station—Case Study

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Abstract Among many other noise sources, living environment is often significantly affected by industrial noise. It is very common in cities that many industrial plants are located near residential areas providing citizens with basic living needs. Noise generated by industrial machines within those facilities strongly affect the quality of life in the close proximity. Goal of the research represents one of the possible solutions of noise-level reduction in the environment affected by a water pump station No. 25, located at Mokroluško brdo in Belgrade. Demands and limitations that have been set during the project solution stage were the main factor for the appropriate noise reduction method. Noise generated by centrifugal water pumps has been analyzed, and acoustic treatment of the technical room is chosen as a solution. Results of the research in the paper represents the possibility of successful application of the surface absorbers available on the market, where price and delivery conditions act as the main factors for the choice of acoustic materials.

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1 Introduction

Water pumping station represents the facility that extract water from the lower to higher level. In the water supply systems, the main purpose of this facility is the transport of the freshwater from the source wells or rivers, or to create water pressure for filling the water tanks. Depending on the capacity, the facility where water pumps are installed has a technical room in which machines are placed (pumps, electromotors, internal combustion diesel engines, compressors, and cranes) and supports rooms (workshops, boiler rooms, ventilation chambers, transformer rooms, sanitary facilities, resting areas, etc.). In the pumping stations what moves liquid from lower to higher depths, a horizontal single-step centrifugal pumps are often used, while vertical multi-step pumps are needed when extraction water from the higher depths [1].

Pumping stations that are parts of the water supply system are often located in the vicinity of the residential areas, due to the supply demands, terrain configuration, and technical reasons. Even though, traffic noise is considered as highest noise polluter, if this kind of facility is installed in the residential area, it significantly affects the quality of life. Despite the traffic noise, where noise level depends of the traffic frequency during the different parts of the day, some industrial facilities, such as described water pumping stations, emit the constant amount of noise often during the entire day (24 h period). The noise spectra of such facilities can in many cases have a tonal component that significantly adds to the noise disturbance. Having in mind the construction and operation of the rotational machines (turbo machines), tonal components in frequency spectrum of the pumping engines are natural and expected, and thus, it will for certain influence the environment.

Under the assumption that number of machinery and operational regimes are defined, the amount of transmitted noise is influenced by the construction and condition of the building facility where water pumps are installed. Problem of the noise control in the vicinity of the pumping station is related to the following steps.

1. Estimation of the existing noise condition in the water pumping technical room, with analysis of the operation regimes and working loads of different pump engines;
2. Estimation of the existing noise condition at the border of the industrial complex and the neighboring acoustical zone. This is determined by measuring the environmental noise level according to the standard [2, 3] and comparing the measurement results with the following step;
3. Calculation of the relevant (authoritative) equivalent noise level at the border of the industrial complex and adjacent acoustical zone, and comparison of with the limit values of the adjacent acoustical zone [4];
4. Technical idea solution for environmental noise reduction generated by pumping engines in the water pumping station, taking into concern the amount of noise that is above the acoustical zone limits, as well as noise limits related to the safe working conditions inside the facility.

2 Study Case—Problem Analysis

2.1 Noise Source Data

Pumping station No. 25 "Mokroluško brdo" in Belgrade is a facility with a purpose of water supply of a city segment at third and fourth height zone. Facility is shown in Fig. 1—left. The facade of the building where technical room is located can be also seen on Fig. 1. The face pf the facade is looking toward the affected object in the vicinity, which can be seen on Fig. 1—middle.

Inside the technical room, six pumping engines are installed (two groups with three of the same type). The distribution of the machines is shown in Fig. 1—right, while technical characteristic can be seen in Table 1.

Fig. 1 Pumping station No. 25."Mokroluško brdo" in Belgrade (left), residential building in the nearby the pumping station (middle), and distribution of the water pump engines in the technical room inside pumping station (right)

Table 1 Technical characteristics of the pumping engines

Electric engine—3 peaces				
Group	Manufacturer	Type	*P* (kW)	*n* (min^{-1})
I	Sever	OKN 6110/4	200	1472
II	Sever	OKN 6130/4	315	1476
Pump—3 peaces				
Group	Manufacturer	Type	*H* (m)	*Q* (l/s)
I	Litostroj	CV9/40-IV-8	146	80
II	Litostroj	5CN9	80	250

2.2 Noise Level in the Technical Room

To solve the noise problem, all of six pumps in the operation regime have been considered. After the series of five measurements with a 5 min interval, mean value of the noise level inside technical room has been obtained $L_{\mathrm{AFeq},t=5\mathrm{min}} = 98.4$ dB. Instrument that has been used for measurements is Brüel&Kjær, type 2270, at the height of 1.5 m from the floor of the room.

2.3 Noise Level at the Receiver

To determine the amount of noise pollution of the environment, generated by water pump station, series of measurements have been taken at the border of the industrial complex and the adjacent territory defined as the strictly residential area without the traffic noise influence. After taking the five measurements in the 5 min interval, average equivalent background noise level has been obtained $L_{\mathrm{AFeq,res},t=5\mathrm{min}} = 44.2$ dB. After turning all of the six water pump engines, process has been repeated under the same conditions, and average equivalent noise level obtained $L_{\mathrm{AFeq},t=5\mathrm{min}} = 68.7$ dB. Measurements has been done without influence of the traffic, due to the fact that traffic frequency is very low during the day and evening, especially during the night.

Results that have been gathered point to the following conclusion

- water pump engines in the absence of traffic represents the dominant noise sources at the given location;
- to reduce the noise level at the given location, it is necessary to undertake certain technical measures to reduce the amount of emitted noise.

3 Study Case—Problem Analysis

3.1 Choice of the Problem Solving Strategy and Task Definition

Solution for the excess noise problem at the receiver position can be done in tri ways [5]:

1. Undertake the technical measures at the noise source by applying enclosure around the sources, where it is necessary to provide nominal operational functionality of the machines and enable easy maintenance access. If entire facility where machines are installed is considered as a noise source, then it is possible to apply the acoustic treatment inside the room (walls, ceiling, etc.) by lining

some of the surfaces with acoustic absorption material, or increase the sound insulation of the facade wall.

2. Undertake the technical measures at the noise propagation path, to increase noise attenuation. In the absence of physical space for planting a dense forest trees or building a mounds, acoustical barrier presents the only option.
3. Undertake the noise reduction measures at the receiver position applying the acoustic treatment on the receiver facade increasing the sound insulation.
   The choice for determining the best strategy from environmental noise reduction generated by pumping station No. 25 “Mokroluško brdo” in Belgrade has been influenced by following factors:

   - Terrain configuration and the spatial placement of the buildings (noise sources and receiver);
   - Shape, dimensions, and orientation of the technical room in relation to the nearby residential objects;
   - Available financial funds at the investor disposal.

Taking into concern the results that has been gathered by noise-level measurements, to solve a given problem, method of acoustic treatment by applying surface absorbers of the water pumping station technical room has been chosen. Additional reason for this decision is the fact that technical room is equipped with a lifting bridge crane, and due to the lack of the available space, using volume type of absorbers was not possible.

Task is defined in such a way that by using the available resources, acoustic treatment of the technical room will be done to reduce the noise levels, in the condition when all of the water pumps are under the working load. In addition, it was important to present the results of the acoustic treatment and corresponding noise reduction using different types of acoustic absorption materials available on the market, and the economic justification versus results of the selected materials.

3.2 Realization of the Task

To realize the given task, following steps has been made [5]:

- By increasing the absorption coefficient value of the sound energy, absorption surface of the partition is being increased:

$$A = S \cdot \alpha \tag{1}$$

  where A (m^2) is partition surface absorption, S (m^2) is partition surface, while α is the frequency defendant absorption coefficient of the material.
- By increasing the absorption coefficient at certain frequency bands, absorption surface at those bands is also increased, which results in the noise reduction at the same frequency bands according to equation:

$$\Delta L_{\mathrm{band},i} = 10 \log \frac{A'_{\mathrm{band},i}}{A_{\mathrm{band},i}}, \tag{2}$$

where $\Delta L_{\mathrm{band},i}$ (dB) is the noise reduction in the ith third octave band achieved by acoustic treatment, $A_{\mathrm{band},i}$ (m^2) is the summation of absorption surfaces of all of the partition in the ith third octave band before acoustic treatment, while $A'_{\mathrm{band},i}$ (m^2) is the summation of absorption surfaces of all of the partition in the ith third octave band after the acoustic treatment.

- Noise levels of the ith third octave band after the treatment is then calculated as:

$$L'_{\mathrm{band},i} = L_{\mathrm{band},i} - \Delta L_{\mathrm{band},i}. \tag{3}$$

- Finally, noise level inside the technical room after the treatment is being determined as:

$$L' = 10 \log \sum_{i=1}^{n} 10^{L'_{\mathrm{band},i}/10}, \tag{4}$$

where i is the number of the third octave band in the range ($i = 1 - n$), $n = 18$ is the total number of third octave bands (100–5000 Hz).

To perform mathematical calculations, following data has been provided:

- Precise dimensions of all of the partitions inside the technical room.
- Values of the absorption coefficient for all of the considered materials based on the available literature [5, 6].
  During the problem solving stage, for graphical representation a software package, *Sketchup* has been used. On Fig. 2, in 1:1 scale, graphical representation of the existing condition of the technical room can be seen. All of the surfaces of interests are made of concrete.

According to the availability on the market, as well as price per m^2, for solving the given problem, following absorption material and construction have been chosen:

1. Polyurethane foam (thickness: 100 mm, density: 25 kg/m^3, fire resistance: B2) is shown in Fig. 3:
2. Rock wool (thickness: 100 mm, density: 50–60 kg/m^3) is shown in Fig. 4. If rock wool is used, it is necessary to apply the protection acoustic transparent net to prevent material particles to float in the air and protect the acoustical absorber layer (Fig. 5).
3. Metal perforated panels are presented on Fig. 6. Construction elements of the metal perforated panel can be seen on Fig. 7.

   - Panel thickness—100 mm;
   - Perforated plate thickness—5 mm;
   - Hole radius—10 mm;
   - Hole distance—40 mm;

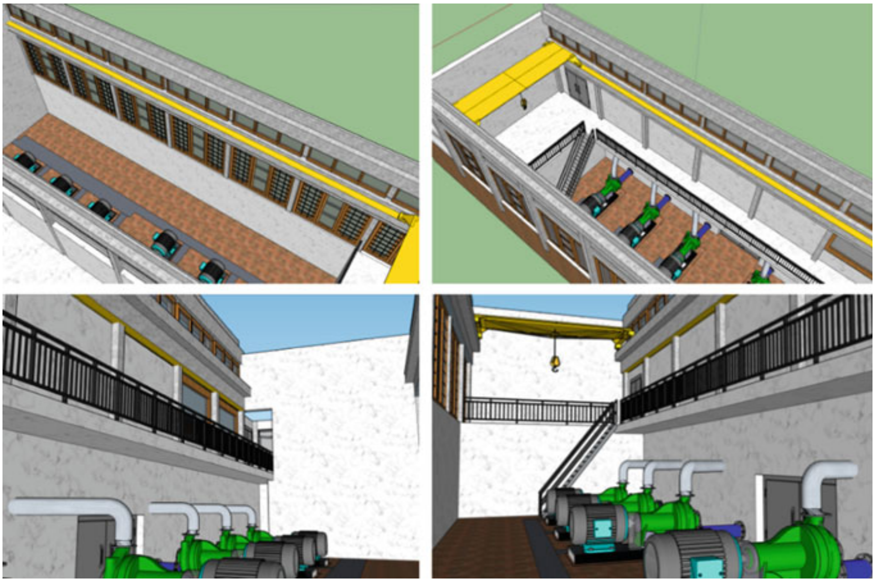


Fig. 2 Graphical representation of the technical room before the acoustic treatment

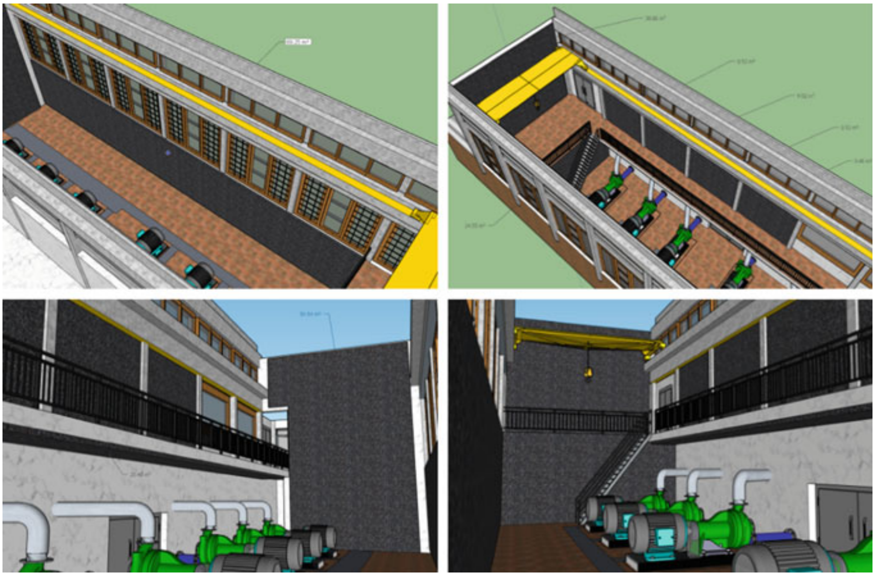


Fig. 3 Graphical representation of the technical room using polyurethane foam for acoustic treatment

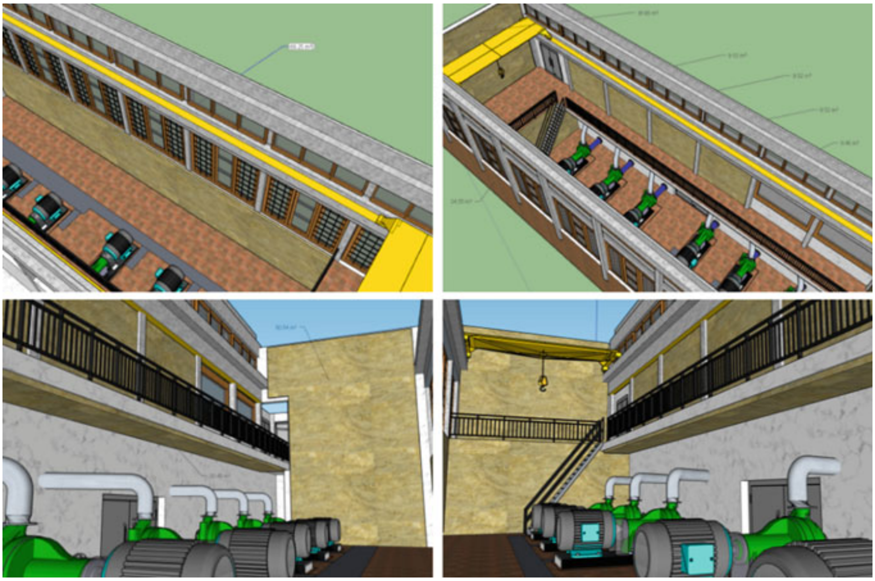
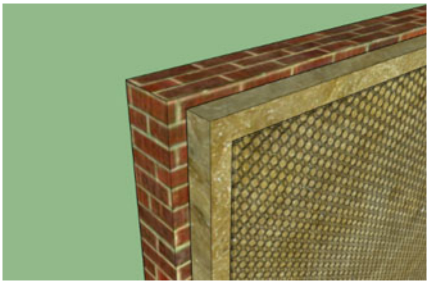


Fig. 4 Graphical representation of the technical room using rock wool for acoustic treatment

Fig. 5 Mounting the rock wool material at the wall surface together with a protection net



- Front plate perforation—19.63%;
- Absorber thickness—75 mm;
- Absorber type—Rock wool with density 50 kg/m^3 or polyurethane foam 30 kg/m^3;
- Air gap—25 mm next to the absorber back plate.
  If rock wool is used, it is necessary to apply the protection acoustic transparent net.

The values of the absorption coefficient for the observed material can be seen on Fig. 8.

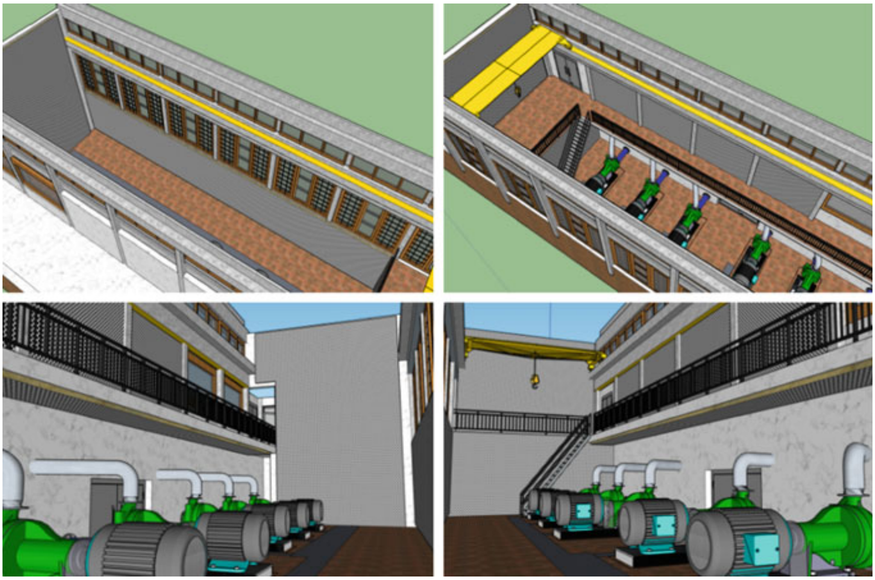


Fig. 6 Graphical representation of the technical room using metal perforated panel for acoustic treatment

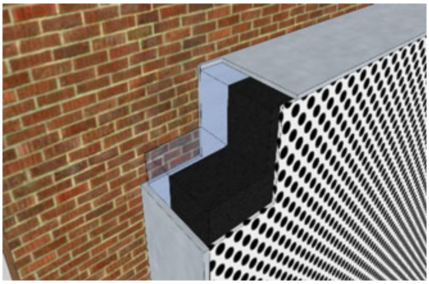


Fig. 7 Cross-section of the metal perforated panel

4 Results of the Research

During the investigation of the optimal solution of the given task (highest noise reduction while using less material), described mathematical approach (2, 3, 4) has been used and applied for cases of surfaces of 240 m^2, 200 m^2, 150 m^2, and 100 m^2 lined with proposed absorption material. Results of the calculation have been presented in Figs. 9, 10, 11, and 12.

First case—lining surface of 240 m^2. Reduction of the equivalent noise level for the polyurethane treatment is 5.40 dB, and for the treatment with rock wool it is 5.34 dB, while for the metal perforated panel, it is 5.40 dB. Difference between calculated

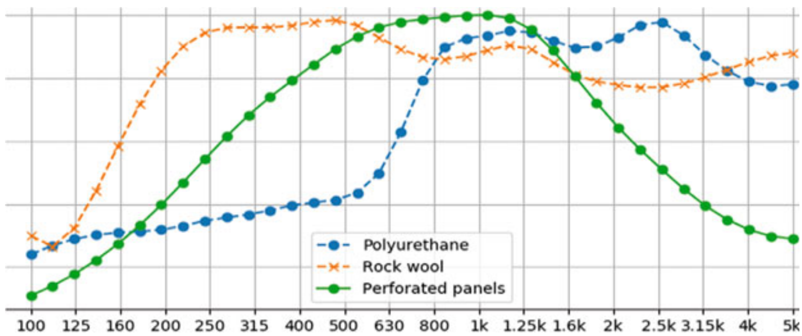


Fig. 8 Absorption coefficient values of the suggested materials (*y*-axis) at the central frequencies of the third octave bands for frequencies 100–5000 Hz (*x*-axis)

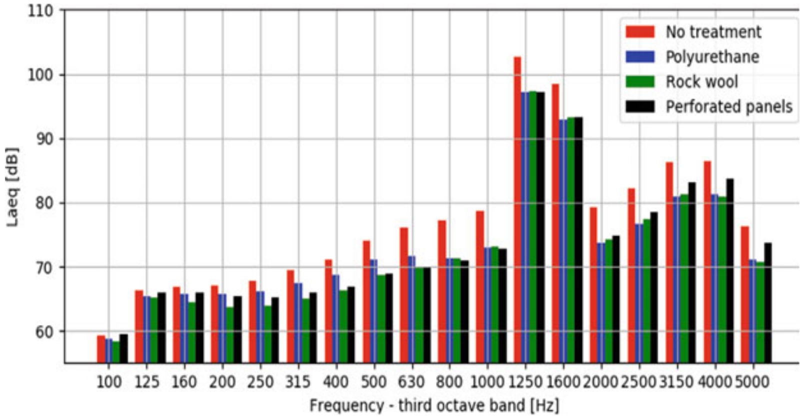


Fig. 9 Results of the noise reduction calculation by applying different acoustic materials with a lining surface 240 m^2

noise levels at the central frequencies 1250 Hz and 1600 Hz must not be higher than 5 dB. If there is a larger difference, noise in the technical room would have a tonal component at the 1250 Hz. If polyurethane foam is used, this difference would be 4.18 dB, and if rock wool is used, it will be 4.02 dB, while in the case of perforated metal panel, this difference is 3.78 dB. Accordion to this criteria, it would be best to use metal perforated panels.

Second case—lining surface of 200 m^2. Reduction of the total noise reduction is 4.46 dB for the case of the polyurethane foam, 4.75 dB if rock wool us used, while 4.86 dB of reduction is gained when using metal perforated panels.

Third case—lining surface of 150 m^2. Reduction of the total noise reduction is 4.17 dB for the case of the polyurethane foam, 4.00 dB if rock wool us used, while 4.06 dB of reduction is gained when using metal perforated panels.

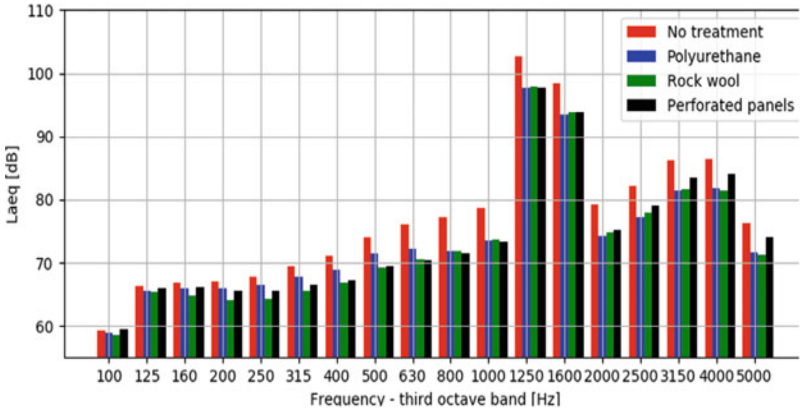


Fig. 10 Results of the noise reduction calculation by applying different acoustic materials with a lining surface 200 m^2

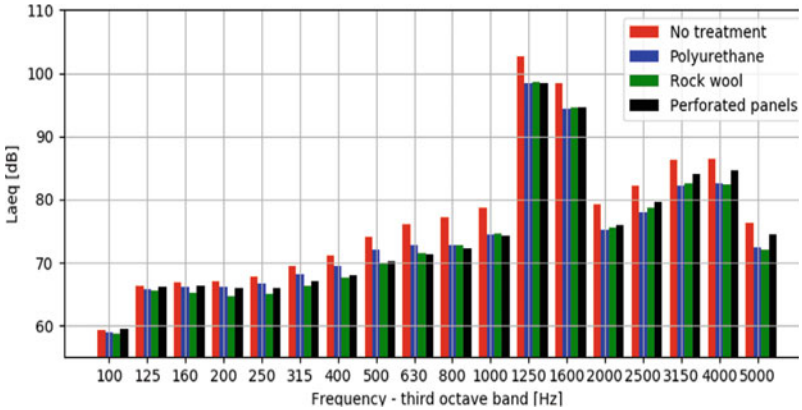


Fig. 11 Results of the noise reduction calculation by applying different acoustic materials with a lining surface 150 m^2

Fourth case—lining surface of 100 m^2. Reduction of the total noise reduction is 3.18 dB for the case of the polyurethane foam, 3.03 dB if rock wool us used, while 3.09 dB of reduction is gained when using metal perforated panels.

Table 2 gives comparative results of the application of different materials in the four listed cases.

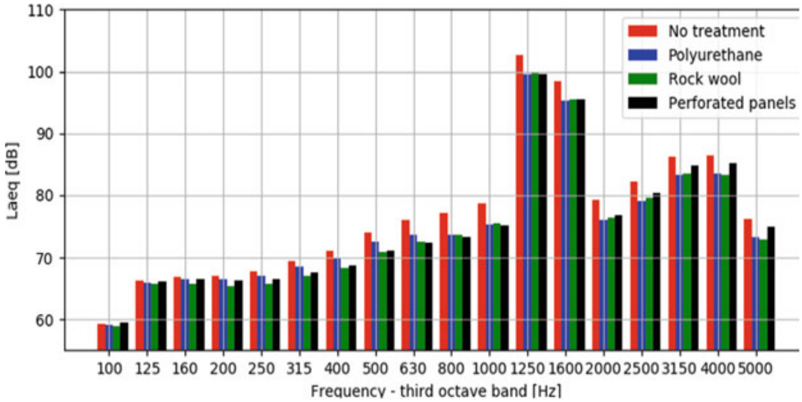


Fig. 12 Results of the noise reduction calculation by applying different acoustic materials with a lining surface 100 m^2

Table 2 Results of the noise reduction using different acoustic materials

Reduction of the total noise level ΔL (dB)			
Surface (m^2)	Polyurethane foam	Rock wool	Perforated metal panel
240	5.54	5.34	5.40
200	4.46	4.75	4.86
150	4.17	4.00	4.06
100	3.18	3.03	3.09

5 Conclusion

Industrial objects especially affect the environment in a negative way if they are in its immediate vicinity. One of the main problems that occurs then is the increased presence of noise.

The case discussed in the paper points to the limited ability to solve the problem, primarily because of the availability of financial resources for taking more serious measures. The results of the research show that acoustic treatment of the technical room of the pump station can achieve a certain reduction in the noise level in the room itself, which would positively affect the noise levels in the immediate vicinity of the pump station. The conceptual solution of the problem is based on market conditions—the possibility of purchasing certain absorption materials and their price, as well as the results (effect) of each of them. The performed mathematical calculation is expected to indicate that the noise-level reduction is directly proportional to the amount of absorption material used for the acoustic treatment of the room, regardless of the material. Bearing in mind the large price difference, it is also shown that the considered construction of perforated metal panels does not have a particular advantage in the concrete case over other materials. Accordingly, depending on the effect desired, the decision on the type and quantity of materials when solving this kind of problem remains at the investor. Certainly, achieving more serious results is expected by changing the facade construction of the technical room of the pump station and possibly replacing the existing machines with modern quieter machines.

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