Managing Environmental Noise with Mobile Noise Barriers - a Case Study of a Dolomite Quarry in Slovakia

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Abstract **– This paper addresses the issue of environmental noise from mining operations, focusing on the specific case of a quarry located in the municipality of Trebejov, Slovakia. The study aims to demonstrate an effective approach to reducing noise pollution through the implementation of mobile noise barriers. The research was motivated by the negative impact of noise from the processing line on the well-being of the population residing in the vicinity of the facility. The study involved conducting extensive noise measurements at various locations surrounding the quarry. The collected data were analyzed to assess the existing noise levels and identify the areas of highest noise exposure. Based on the findings, the implementation of mobile noise barriers was proposed as a solution. The results of the study demonstrated that the mobile noise barriers successfully reduced the noise levels below the legal limits, significantly improving the well-being of the population living near the quarry. The case study opens up the possibility of using mobile noise barriers in other areas and operations with high noise exposure.**

Keywords **– Environmental management, noise barriers, environmental noise, permissible values, quarry production line.**

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1. Introduction

Environmental noise is a significant problem in Europe, with many people living in areas that are exposed to high levels of noise pollution. The European Environmental Agency (EEA) estimates that approximately 100 million people in Europe are exposed to noise levels that exceed the recommended levels set by the World Health Organization (WHO). These high noise levels can lead to a range of health problems, including hearing impairment, cardiovascular disease, and sleep disturbance. To address this issue, the European Union has established noise-reduction policies and regulations, such as the Environmental Noise Directive (END) which sets noise limits for major sources of noise pollution. The main sources of environmental noise are mines and quarries. Quarries are a source of environmental noise pollution, particularly for nearby residents. The noise generated by quarrying activities can come from a variety of sources, including blasting, drilling, crushing, and hauling of rock and minerals.

The noise levels from quarrying can be quite high, and can cause a range of health problems for people living nearby, including hearing impairment, sleep disturbance, stress, and annoyance. In addition to the health effects, noise pollution from quarries can also have negative impacts on wildlife, including birds, mammals, and amphibians, which may be disturbed by the loud noise and vibrations.

There are numerous scientific studies that have examined the impacts of noise from quarries on human health and the environment. Studies from different areas of the world provide evidence that noise pollution from quarries can lead to a range of negative health effects, including hearing impairment, sleep disturbance, and stress [1], [2], [3]. However, noise from mining activities also affects the wider surroundings of the mining operation.

A studies by [4], [5] found that noise from quarrying activities can have negative impacts on wildlife, including birds, which may abandon their nesting sites in response to loud noise and vibrations.

A negative impact of noise from quarries in terms of a reduction in the quality of life for nearby residents was reported in the study of [6]. Moreover, noise and other adverse effects related to mining operations can diminish property values and destabilize existing local communities [7]. Several studies indicate that exposure to noise from quarrying activities can have negative impacts on cognitive function in children [8], [9], [10].

Despite the lack of studies from European countries, the scientific evidence suggests that noise from quarries can have significant negative impacts on human health and the environment, and that measures should be taken to mitigate these impacts.

To mitigate the impact of quarry noise, measures can be taken to reduce noise emissions. These include the use of noise barriers, such as berms or walls, around the quarry site, and the implementation of noise-reduction measures on equipment, such as mufflers or silencers. In some cases, quarry operations may be required to limit the hours of operation or reduce the intensity of the noise generated by their activities.

Regulations on quarry noise pollution vary by jurisdiction, but many countries have established guidelines and regulations to limit the amount of noise that can be generated by quarry operations. These regulations may require quarry operators to monitor and report their noise emissions, and may establish penalties for non-compliance.

The EU also provides funding for noise-reduction measures, such as the installation of noise barriers along highways and railways, the use of low-noise pavement, and the implementation of traffic management schemes. Despite these efforts, however, noise pollution remains a significant problem in many areas of Europe. The European environmental agency reports that noise levels have remained relatively stable over the past decade, and that noise pollution continues to be a major environmental health concern in Europe [11].

Based on a case study of a quarry company in Slovakia, a series of measures are presented that have led to a reduction in environmental noise below the legal limits.

2. Case Study Outline

Production at the Trebejov quarry processing line started with a trial run in August 2016.

The designed production capacity of 250 t/h of dolomite fractions for chemical-technological processing has been reached. In two-shift operation, up to 750 kt/year can be produced. Production is fully automated, controlled by two operators using computers that monitor a number of parameters. Modern technologies have been used in the construction of the plant, with emphasis on environmental protection and public health. By changing the location of the line, the secondary and tertiary parts of the line have been made more exposed. As with any quarry production line, the negative impact of production on the environment had to be addressed.

3. Identification of Noise Sources

The noise study focused on impact of operational noise on the environment was part of the project documentation of the quarry operation. According to its conclusions, the permissible noise levels should not have been exceeded and there should have been no deterioration in the living conditions of the population in terms of noise compared to the existing situation, but on the contrary, there should have been a reduction in the emission of noise levels compared to the original quarry line.

After the quarry line was put into operation, measurements showed that the noise levels exceeded the permissible limits for the environmental noise.

In order to design effective noise abatement measures, a visualisation of the noise sources on the secondary line was prepared. A noise visualisation tool - an acoustic camera - was used for a more detailed analysis and to identify and locate the noise sources. The Acoustic Camera is a versatile tool that is well-suited for measuring complex noise emissions from large sources. It enables precise identification and subsequent quantitative and qualitative analysis of the noise. The camera's set of devices allows for spatial localization of noise emissions and provides frequency analysis in dynamic mode. It can accurately analyze noise sources from distances ranging from tens to hundreds of meters. The accompanying software can efficiently locate noise sources, perform both qualitative and quantitative analysis, and offer a basis for noise emission reduction measures.

The measurement and subsequent analysis with the Acoustic Camera is characterized by high accuracy, speed, and efficiency, and operates dynamically. The tool offers clear processing of the results in the form of color noise maps, videos, and sound recordings.The results of measurement are visualised in Figure 1.

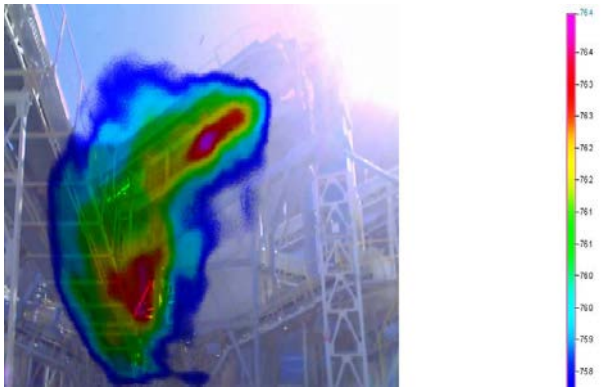

Figure 1. Noise visualisation on the sorter

The noise assessment was carried out in accordance with the relevant basic national and international standards and methods. Based on the measurements taken, the dominant noise sources were found to be the two sorters, followed by the crushers and the loading of aggregate onto vehicles.

4. Implementation of Noise Abatement Measures

In order to reduce noise pollution, a number of noise abatement measures have been implemented during the operation of the quarry. The abatement measures consist of:

- Noise barrier at the dispatch and the crushers.
- Noise reduction on the impact surfaces at the processing plant.
- Noise reduction on the sorter and crusher using mobile echo-barriers.

4.1. Noise Barrier at the Dispatch and the Crushers

In 2018, a noise barrier made of ISOLAMIN PA 33P 80 perforated panels was built. A project with static calculations was prepared. The wall was built in the expedition site by the car loading path of the 8,000 x 2,550 mm conveyor belt, as the noise was generated when the 16x45 mm fraction truck bed was hit. A wall was then built opposite the crushers on a secondary line measuring 15,000 x 3,000 mm (see Figure 2).

Figure 2. Noise barriers at crushes

4.2. Noise Reduction on the Impact Surfaces at the Processing Plant

Impact surfaces at the treatment plant. Noise from crushing, screening and process roads at the treatment plant is largely dependent on the design of the impact areas on the material transport routes at the treatment plant and the size of the aggregate. Another measure was to line the impact areas with polyurethane plates with magnetic or screw fixings (see Figure 3).

For this purpose, polyurethane abrasion-resistant plates with a thickness of 30 mm or 40 mm were used for the impact areas (slip under the sorter, impact surfaces on the sorter, shaft protection on the sorter, spillways to the conveyor belts, feeders, and frontal impact surfaces. The advantage of these plates is that, in addition to the noise reduction, they significantly reduce the wearing of the original construction frame and undesirable crumbling of the material.

Figure 3. Noise reduction in front wall of the hopper on the roller crusher

4.3. Noise Reduction on the Sorter and Crusher Using Mobile Echo-Barriers

Particularly challenging for noise abatement were the secondary line locations, specifically the sorters and crushers, due to their complex design and more difficult accessibility.

At the same time, these were the locations where the highest noise emissions were measured. The use of mobile echo barriers appeared to be a suitable solution. These are flexible panels measuring 2050mm x 113mm and 40mm thick. They are lightweight, weighing only 3kg/m^2. The panels have 25mm diameter metal rings around the perimeter through which a cable can be passed and attached to the structure. They do not require a separate support structure.

Their advantage is that they can be easily removed if required. The panels reduce noise levels by 10 to 20dB. Application of mobile noise barriers is presented in Figure 4.

Figure 4. Mobile Echo Barrier and its location at the sorter

5. Measurement and Evaluation of the Noise Impact of the Production Line to the Nearest Protected Outdoor Areas

Based on the assessment of the noise situation, the measuring points were chosen in front of the family houses in Trebejov No. 16 No. 75. In both cases, the microphone of the sound level meter was placed on a tripod at a height of about 1,5m ± 0,2m above the floor level and at a distance of 1,5m ± 0,5m in front of the facade with the windows of the living rooms.

The measurement was carried out during normal operation of the production line at the Trebejov quarry and normal traffic associated with the operation of the quarry. Orthomap of the area and measurement points are captured in Figure 5.

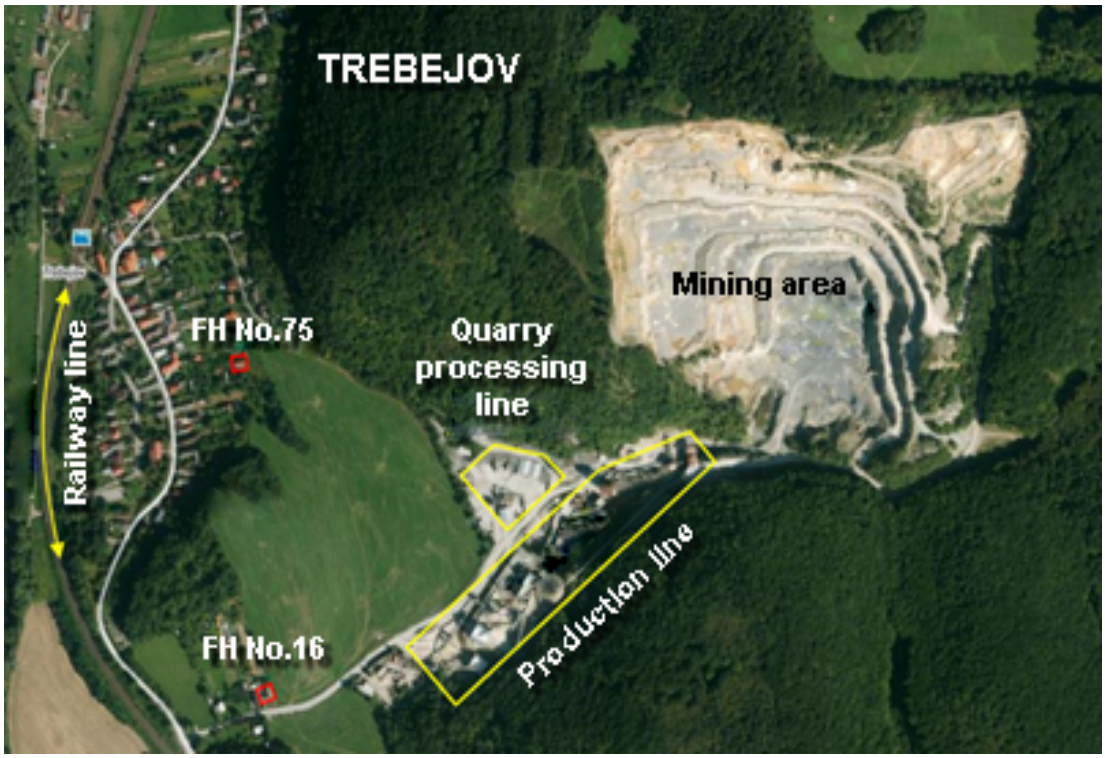

Figure 5. Orthomap showing measurement points and noise sources

Background noise measurements were made at the same locations after the production line had ceased operation, when no activity was taking place in the Trebejov quarry operation.

The results were continuously stored in the memory of the sound level meter and subsequently evaluated by computer in the CesvaLab program.

During the measurements, the sound level meter was set to the mode with periodic storage of the measured samples.

The permissible values of noise in the outdoor environment are established by the Decree of the Ministry of Health of the Slovak Republic No. 549/2007, which establishes the permissible values of noise, infrasound and vibration and the requirements for the objectification of noise, infrasound and vibration in the environment and Act 355/2007 on the protection, promotion and development of public health and on the amendment and supplementation of certain acts, as amended.

In general, the legislation sets out two types of noise limit values:

- Lden: The day-evening-night noise indicator (Lden) is a measure of the average noise level over a 24-hour period, with different weightings applied to noise during the day (6a.m. to 10p.m.), evening (10p.m. to midnight), and night (midnight to 6 a.m.). The limit values for Lden are:
    - 55 decibels (dB) for outdoor residential areas
    - 60 dB for outdoor areas that are not primarily residential, such as commercial or industrial areas
    - 50 dB for indoor areas in schools, hospitals, and other buildings where people need to sleep
- Ln: The night-time noise indicator (Ln) is a measure of the average noise level during the night-time period (11p.m. to 7a.m.). The limit value for Ln is:
    - 45 dB for outdoor residential areas.

Permissible limit values for environmental noise pollution according to EU legislation that were adopted also in the condition of the Slovak republic are captured in Figure 6.

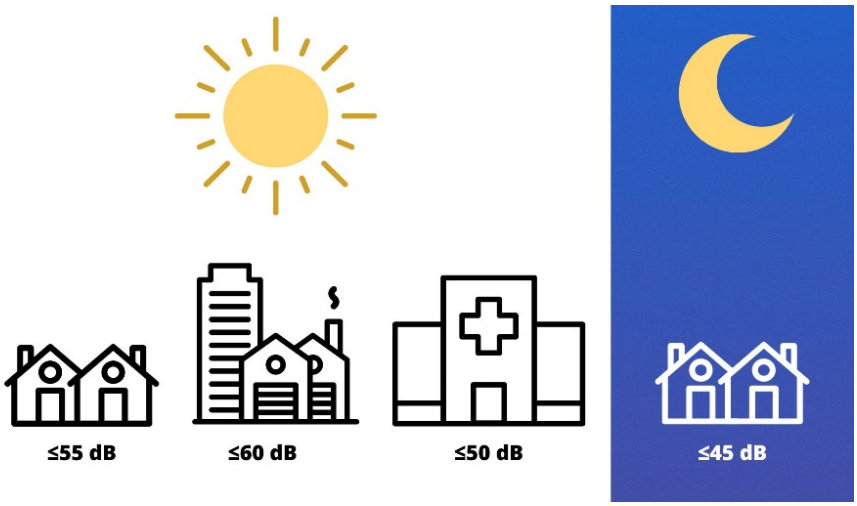

Figure 6. Permissible limit values for environmental noise

The determinant, i.e. the equivalent sound level A LAeq, determined on the basis of measurements and taking into account the temporal exposure of the noise source under consideration, determined for the relevant reference time interval, is given in the Table 1 and Table 2.

According to the Decree of the Ministry of Health of the Slovak Republic No. 549/2007, which establishes details on permissible values of noise, infrasound and vibration and on requirements for the objectification of noise, infrasound and vibration in the environment, as amended, the outdoor area in front of the windows of family houses is classified as category II. The permissible value of the equivalent A sound level in the outdoor environment, established for the category II area, is set as follows for noise from other sources and road traffic noise:

$$\text{day } L_{Aeq,p} = 50 \text{ dB}$$

The expanded measurement uncertainty U = 2,0 dB was determined on the basis of the spectral composition of the noise and the orientation of the measuring microphone to the dominant noise sources in accordance with the Expert Guideline on the Determination of Uncertainties in Sound Measurement [12].

6. Results

The results of measurements after the implementation of several noise abatement measures during the four-year period in the quarry near the village of Trebejov are shown in Table 2 and Table 3. Two measurement points were selected in the village residential area, where the noise exposure was the highest.

As is evident from Table 1 and Table 2, after the implementation of all noise abatement measures in the most noise intensive spots, the noise exposure has been reduced below the legally permissible values.

Table 1. Evaluation of the noise exposure in Trebejov quarry operation (measurement point 1)

Trebejov quarry operation			
Place of measurement: In front of the facade of Family House No. 16 in Trebejov			
Measurement	Measured value + U (dB)	Permissible value (dB)	Evaluation
2018	53.9 + 2.0	50	Exceeded
2019	51.4 + 2.0	50	Exceeded
2020	48.6 + 2.0	50	Exceeded
2021	47.8 + 2.0	50	Not Exceeded

Table 2. Evaluation of the noise exposure in Trebejov quarry operation (measurement point 2)

Trebejov quarry operation			
Place of measurement: In front of the façade of Family House No. 75 in Trebejov			
Measurement	Measured value + U (dB)	Permissible value (dB)	Evaluation
2018	51.9 + 2.0	50	Exceeded
2019	50.4 + 2.0	50	Exceeded
2020	48.9 + 2.0	50	Exceeded
2021	46.8 + 2.0	50	Not exceeded

7. Conclusion

Every quarry operation with a processing line has minor or major noise and dust problems, depending on the distance from a residential area. This paper presents a case study of a quarry in the municipality of Trebejov to demonstrate the potential for noise and dust reduction through the use of noise barriers. The noise reduction was achieved by a combination of several noise abatement measures, including noise barriers at the dispatch and the crushers, noise reduction on the impact surfaces at the processing plant and noise reduction on the sorter and crusher using mobile echo-barriers. Thanks to these measures, compliance with the requirements of the legislation has been achieved. Secondary benefits are reduced dust from quarry production and, in the case of the insulation of the impact surfaces at the processing plant, protection of the equipment from abrasion and wearing.

Although the noise levels are now below the legal permissible values, there is still room for improvement. An additional measure will include the creation of a park behind the village.

This will reduce noise pollution, improve the landscape and reduce dust caused by traffic. Appropriate trees or shrubs will also be planted along the access road to the quarry, which could further reduce noise pollution and improve the environment for residents.

Moreover, integration of management systems focused on environmental protection, health and safety [13] may increase overall performance of the company and improve the relationship with local community.

The case study can serve as an example of best practice in noise abatement actions for other similar operations in mining industry as well as other noise intensive industries. Mobile noise barriers, in particular, appear to be widely applicable due to their flexibility and variability, which opens up possibilities for their application in e.g. transport or construction.

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