Analysis of the effectiveness of noise abatement measures in relation to the type of train

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Abstract. The paper is focused on the comprehensive analysis of the railway noise issues. Not only does it deal with the influence on the environment, but also with the Czech laws in this field. Moreover, it presents all the options how the noise from the railway transport might be reduced and several proposals how to increase effectiveness of noise protection. In conclusion, the theoretical part is complemented by a practical one in the form of measuring and subsequent analysis.

1 Introduction

Sound is one of the fundamental and inherent parts of the environment and the world we live in. People get a remarkable piece of information thanks to it. In essence, this is a gradual longitudinal mechanical waving of the elastic environment that is perceived by the hearing. It is formed by the vibration of liquids, bodies or air, either on the basis of natural phenomena occurring in the environment or human activities. Human hearing is capable of capturing sound ranging from 20 to 20,000 Hz. [1]

For the purposes of this paper the noise is considered as any sound that is unwanted or has adverse or unpleasant effects on our organism. There are a number of professional definitions, but in general it is a sound that disturbs, harms, or damages (health, property, or the environment). It is important to note that it is not decided on the basis of physical parameters whether the sound is noise or not but purely by considering subjective feelings.

Rail transport is much more environmentally friendly than road transport, but noise can pose both a health risk for people living near the track and an obstacle to building new routes. Therefore, it is necessary to emphasize the correct location and construction of anti-noise measures, as well as their further development.[2]

2 Noise’s impact on the environment

Especially effects on humans and animals are analysed. The whole chapter draws mainly from the information of the State Health Institute and the information provided by the doctors and assistants of the Occupational Disease Ambulance of the University Hospital in Ostrava-Poruba.

For simplicity, these negative effects of noise on humans can be divided into organ effects, activity disruption (insomnia), or effects on subjective human feelings (harassment). Also, noise can cause deterioration of existing illnesses that have multifactorial causes.

The organ effects can be further divided into specific and non-specific. By non-specific we mean an effect on multiple organs, influencing their activity on the basis of stress or nervous irritation. Specific include disorders of hearing and hearing organs.

Generally, we most commonly experience hearing damage due to noise (increased hearing threshold, poor speech comprehension, tinnitus, etc.), cardiovascular system (increased blood pressure, pulse and vasoconstriction), sleep disturbances or even noise harassment. [3]

3 Legislative framework of noise impact on human health

The legislative regulation of this issue in the Czech Republic contains a number of legal norms, some of which are based on EU law and international standards. Below we choose the two most important ones.

3.1 Decree No. 107/2013 Coll.

For the purpose of assessing the impact of physically or mentally demanding work on humans, the Government of the Czech Republic issued on 22 April 2013 Decree No. 107/2013 Coll. for categorizing positions where workers are exposed to increased dust, chemical toxic substances, noise, vibration, non-ionizing radiation, cold, heat, physical or mental stress, or work in unfavorable or elevated air pressure.

In the second category, workers are exposed to steady or variable noise with an equivalent sound
pressure level in the range of 80 to 84.9 dB (A) and a peak sound pressure level in the range of 130 to 139.9 dB (A). For the third category, 85 to 105 dB (A) at steady or variable noise and 140 to 150 dB (A) for peak sound pressure apply. At higher values, these employees belong to the fourth category. High-frequency noise, ultrasound, infrasound and low-frequency noise are not considered for these purposes. [4]

3.2 Government Regulation No. 272/2011 Coll.

Pursuant to Directive 2002/44 / EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents, on 24 August 2011 the Government of the Czech Republic issued Regulation No. 272/2011 Coll. on the protection of health from the adverse effects of noise and vibrations. This regulation lays down, inter alia, hygiene limits for noise and vibrations at workplaces, the way they are identified and evaluated, and the minimum scope of protection measures for the employee. [5]

Under Section 3, the permissible exposure limit for steady and variable noise at work is equivalent to an 85 dB (A) sound level or 50 dB (A) for workplaces where work is demanding for concentration, attention or creative work. For other workplaces where production or storage activities are carried out, and the noise is not produced by the works itself, but a 70 dB (A) limit is applied to the ventilation or heating equipment. Section 4 deals with impulse noise limits. These are also determined by this Regulation at 85 dB (A), at a peak sound pressure level of 140 dB (A).

Section 9 contains recommendations and regulations for employers. Employees who carry out noise-related work above the permissible values must be adequately trained, especially for the use of protective equipment at work (hearing protectors). These workers are also entitled to a safety break (beyond the exposure to noise exceeding the permissible exposure limit) for at least 15 minutes after two hours of work, and then at least 10 additional minutes after every two hours. The last break must be placed no later than one hour before the end of the shift. The employer must ensure regular and proper maintenance of the means of production, equipment and work tools so that their wear rate is not the cause of noise increase.

If the measurement evaluation reveals that noise during the eight-hour shift exceeds 80 dB (A), the employer shall provide hearing protection devices effective in the area of the frequencies of the noise. If the 85 dB (A) limit is exceeded, the employer must ensure that employees use the aids provided. [6]

4 Possibilities of removing noise in railway transport

The most important source of noise in the Czech Republic is the transport infrastructure. Rail transport is generally ranked among modes of transport that are environmentally friendly. Compared with other transports, this is indeed the case, especially in the area of CO2 emissions and other harmful substances discharged into the air by combustion engines. The component that causes the greatest problems for railways in relation to the environment is noise. In order to address noise abatement options in rail transport, it is first necessary to analyse its sources. [7]

Noise emissions from rail transport cannot be generalized as they come from many sources whose intensity varies depending on the speed and design of the train as well as on the surface of the railway superstructure. When comparing more studies, we can say that at speeds of up to approx. 40-60 km / h the most significant noise is the one of the traction engine. From approx. 40-60 to approx. 160-200 km / h the rolling noise prevails and at higher speeds the dominant aerodynamic noise (see graph in figure 1). The noise of the collector and the local traffic noise are among the less significant but not negligible.

An important role in the spread of noise from rail transport is also played by the current weather situation. This is especially true in distances over 100 meters, but sometimes even in smaller ones. Snow may also absorb some of the noise or there might be a reflection of sound from different layers of air. Higher air humidity usually also leads to better propagation, so that noise can go even further than dry air.

With the current state of the Czech railway infrastructure, we can easily find that the biggest problem in the Czech Republic (and indeed in Slovakia) is just the rolling noise. That is why most anti-noise measures focus on this source. We can basically divide noise-reducing measures into active ones that restrict the sound of noise (noise emissions) and passive ones, which reduce noise and its impact on the environment (noise pollution).

We can then divide the active noise measures into four groups: urban-architectural, urban-transport, traffic-organizational and technical.

Urbanistic and architectural anti-noise measures relate to construction itself. The process of spatial planning and the comprehensive solution of residential units in terms of their functional layout is quite essential. In particular, it is good to locate buildings depending on the location of other sources of noise. These include concentrating these units into blocks that are perpendicular to the noise source, or building terraced objects near sources. As far as the reflection is concerned, it has been found that the reflection takes place at the highest intensity at a height of about ten meters above ground, so we should place high-rise buildings and communications away from noisy roads.

Urban-traffic noise pollution measures are also closely related to spatial planning in conjunction with transport. Long-term transport infrastructure planning needs to be adequately organized at all levels (national, regional and local). As a concept, these measures are covered by a set of many urban and transport road and rail transport tools that can be combined, including the management of new roadways away from protected buildings, tracing motorways of both classes and first class roads outside residential areas and other areas with
higher demands for noise protection (nature reserve, etc.), optimizing transport rights and improving transport relations, minimizing transit traffic in city centers and residential areas, minimizing heavy freight traffic in the vicinity of residential areas, creating conditions for preference of mass transport and limiting individual transport within cities and agglomerations, not allowing planning of new acoustically sensitive construction near to the busy roads, the location of parking areas and other transport areas at a sufficient distance from protected buildings, the limited time of entry of supply vehicles in city centers and other sensitive locations and the concentration of different modes of transport main routes and corridors with the possibility of creating uniform noise measures (a successful example is road and railway track jointly led by several kilometers near Hraděk stop, see Figure 1). [2]

![Fig. 1. The common noise barriers of the road and railway in the Jablunkov region](image)

Traffic-based anti-noise measures are such as to limit or modify traffic in order to minimize either noise alone or its negative impact. In railway practice, this includes in particular a reduction in line speed; eliminating where you need to reduce the train speed; more efficient traffic management to reduce stopping for transport; relocation of noisy transport processes (for example, changing the place for shunting in a hilly hill or HVV exchange); or even the reorganization of the circulation of the railway vehicles (so that the lesser noisy ride on the affected section). In particular, technical noise suppression measures have the advantage that it is often possible to establish them retrospectively, even after many years of construction, based on noise reduction requirements. The essence of the technical basis of rail transport means that these measures can be carried out either on railroad tracks or other stationary tracks or directly on the vehicles themselves.

Regular maintenance, grinding and milling of rails, complete overhaul or application of rail absorbers are essential and necessary measures for the track. The disadvantage of these measures, however, is the fact that they are only local in the area of vehicle modifications.

For the rolling stock, a complete upgrading or modification of the chassis and wheel silencers is considered. Another option is to replace the classical cast iron brake jaws with more modern composite materials, reducing not only the braking sound itself, but also the fact that the cast iron blocks rough the surface of the wheels and thus increase the rolling noise (up to 50%). The advantage of vehicle measures is that they reduce noise across the rail network, but for sufficient efficiency they need to be applied to a considerable number of vehicles, which entails considerable investment costs.

Other measures in the runway environment can be broad stripes of greenery, which can be combined with earth valleys. Their advantage is that they capture not only noise, but also dust. They also often have a higher aesthetic level, thus enriching the surroundings of the noise source. The most significant disadvantage is that in the winter when deciduous trees fall, the effectiveness of this measure will be significantly reduced. [8]

### 5 Analysis of the effectiveness of noise reduction measures

For the first measurement, we chose the locality near the Ostrava-Svinov railway station in the direction of Hranice na Moravě (261st km of the railway line SŽDC number 270). The area on the main track was deliberately chosen on the one hand because of the high frequency of trains and because of the fact that many different types of trains are being driven here. The concrete sites were also meeting the requirements for the presence of the absorption noise barrier, even without it, but the advantage was that recently, in the immediate vicinity of the noise barrier, a new road road linking the D1 motorway exit and the Ostrava-Svinov station was completed and built on a raised embankment, which made it possible to partially shade ambient noise not coming from rail transport (see Figure 2).

![Fig. 2. The place of the first measurement](image)

For refinements, we have repeated measurement in other locations. Specifically, at the head of the station Suchdol nad Odrou towards Ostrava (233rd km of the railway line SŽDC number 270). We chose this place on the one hand because of the favorable conditions for noise measurements outside and beyond the wall, but also because of the wider range of vehicle types (for example motor coaches in the local lines which we could not measure in Svinov).[9] Another advantage was that some types of trains (express train and passenger trains) stop at this station, but others (EuroCity, SuperCity) drive through it; this helped us in the subsequent analysis...
of starting, braking and passing noise. Further measurements took place in Žilina, the local part of Brodno (4th km of ŽSR line 127). The air temperature during measurements was approximately 4 °C and the air humidity was approx. 50%. In some cases, the noise of the train was exceeded significantly by the noise of the sound signals. However, elimination of these signals can lead to several risks to the carrier as well as the manager of infrastructure and therefore these results are not considered relevant. [7] [8]

![Figure 3](image1.png)

**Fig. 3.** Comparison of the noise of individual train types in the second measurement

Figure 3 presents the aggregate measurement results and the asbestos differences in acoustic pressures. Percentage of noise reduction is shown in Figure 4.

![Figure 4](image2.png)

**Fig. 4.** Total absorbed noise absorption depending on the type of trains

The most effective was the noise barrier for freight trains, the least for units. By considering the fact that freight trains are the loudest and units seem to be the quietest, we can easily infer the logical conclusion that the volume of sound pressure that the wall is able to absorb is not absolute, but directly proportional to the magnitude of the sound pressure coming from the source. On average, however, these walls reduce the noise by more than one tenth, which may seem like a relatively small number, but when compared to the noise thresholds causing permanent health effects, we can judge that these walls can be crucial for human health. In addition, the fact that the decibel scale is logarithmic and therefore a small drop or increase in the measured sound pressure may result in a jump difference in human perception.

From the measurement results, we have also concluded that even though the noise value decreases relatively slowly over longer distances, it decreases considerably at a smaller distance. Therefore, the dependence of the distance on the resulting measured value is not directly proportional, and thus even a small distance change of the exposed subject or building can be key to negative effects of noise.

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