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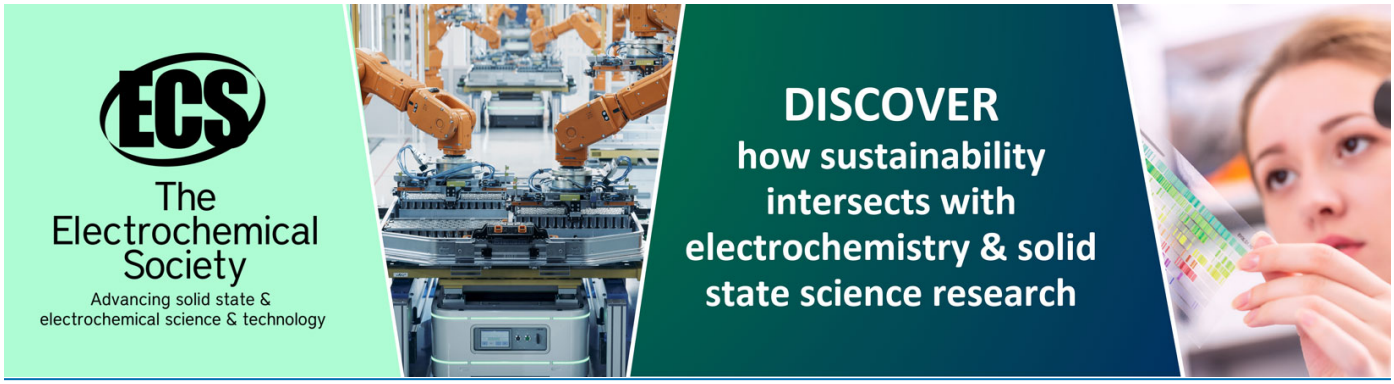

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Environmental Protection Against Noise and Vibration

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Abstract. Noise in large cities reaching the interior of buildings by air or in the form of material noise caused by vibrations propagating through the ground to the building not only cause discomfort but also pollution according to legal regulations in the field of environmental protection. The main legal acts in Poland relating to environmental protection are the Environmental Protection Law of 2001, as amended. Under the concept of emissions in this act, the introduction of substances or energy into the environment, such as heat, noise, vibrations or magnetic fields. Pollution, is understood as an emission that may be harmful to human health or the state of the environment, may cause damage to material goods, may deteriorate the aesthetic value of the environment or may conflict with other, justified ways of using the environment. According to a 2008 Directive of the European Parliament and Council, pollution is direct or indirect introduction of substances as a result of human activity, vibration, heat or noise to air, environment water or soil that may endanger human health or environmental quality, or manifest itself in the form of damage to tangible property, diminution of value or collision with other legitimate uses of the environment. The above two legal acts already show that both noise and vibrations should always be taken into account in the environmental impact assessment. The paper also analyzes other acts of law relating to environmental protection, taking into account noise and vibrations. Moreover, possible solutions that can reduce pollution such as noise and vibrations are clearly described.

1. Introduction

We are constantly exposed to noise and vibrations. They negatively affect human health and the service life of devices. Exceeding the levels of noise and vibration emissions (mechanical vibrations) harms human health [1-2], and also causes material losses resulting from possible damage to the technical infrastructure of buildings and devices. Therefore, it is important to take any preventive actions in accordance with the requirements regulated by law and technical standards.

Protection against noise consists in ensuring the best possible acoustic state of the environment. In particular, by keeping the noise level below the permissible level or at least, and reducing the noise level to at least the permissible level when it is exceeded. Statistically, it was found that the human hearing organ is adapted to receive sound waves with a frequency of 16 to 20,000 Hz and acoustic pressure ranging from 20 μPa to 10 Pa. The ear plays the role of a circuit that detects the direction, volume, pitch and timbre of a sound. It is worth to underline that sounds at certain frequencies are inaudible. Sounds with frequencies lower than 20 Hz (16 Hz) are called infrasound, while sounds with frequencies higher than 20,000 Hz are called ultrasounds [3] and are inaudible to humans. The intensity of a sound is most often defined for the conditions in which it is inaudible and in which pain is felt. It can therefore be said

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that the auditory sensation is limited from below by the threshold of sensitivity, and from above by the limit of pain.

Hearing sensitivity is not constant, it is high at low sound levels and low at high levels. The phenomenon of a change in hearing sensitivity as the level changes is called adaptation. Adaptation plays a role in the body's defense against the long-term effects of noise [4]. The problem of the impact of noise on the human body is complex.

It concerns human as a biological organism, intellectual unit and member of a social group, as well as all manifestations of his life. Noise affects not only the hearing organ, but also other organs via the central nervous system. The effect of noise on mental health is also important.

There is a problem with social awareness regarding to the influence of vibrations on human body, people always relate health problems caused by vibrations with whole body vibrations which happens during the work, ex. work with vibratory hammer, bus driver etc. Vibrations can not only be annoying but also in long duration period can have significant influence on human health. Low-frequency vibrations up to 25-30 Hz which are often generated by urban transport, because of its characteristics can be harmful. Low-frequency vibrations are close to resonant frequencies of internal human body organs (Figure 1.) and can provide some medical symptoms which are listed in Table 1 [5].

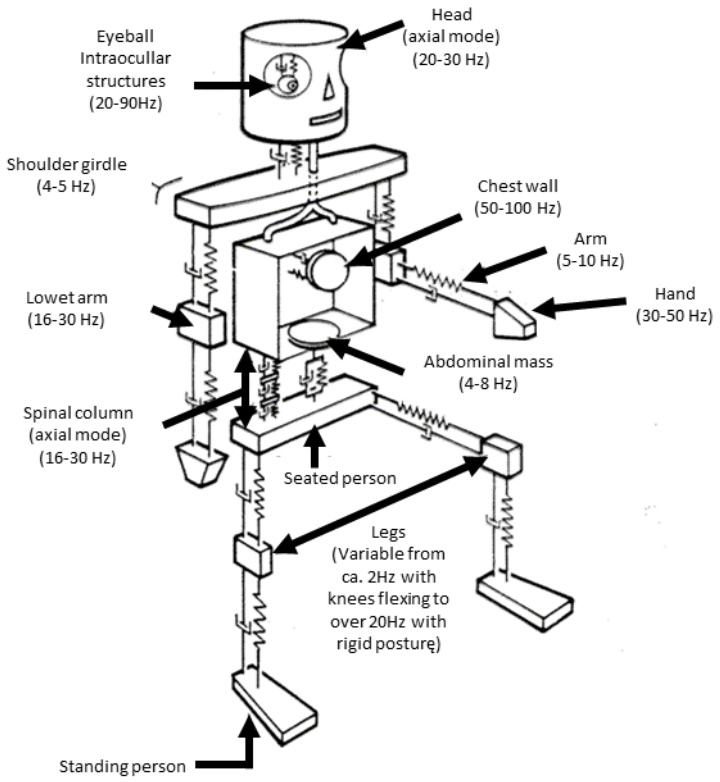

Figure 1. Resonant frequencies of human body, based on [5]

Table 1. Human body symptoms due to vibrations.

Symptoms	Frequency [Hz]
General feeling of discomfort	4-9
Head symptoms	13-20
Lower jaw symptoms	6-8
Influence on speech	13-20
"Lumb in throat"	12-16
Chest pains	5-7
Abdominal pains	4-10
Urge to urine	10-18
Increased muscle tone	13-20
Influence on breathing movement	4-8
Muscle constractions	4-9

2. Noise measures and levels

In the further analysis of the impact of noise on the human body, we will consider sound level A. Sound level meters used in practice are equipped with special frequency correction filters: A, B, C and D (see Figure 2).

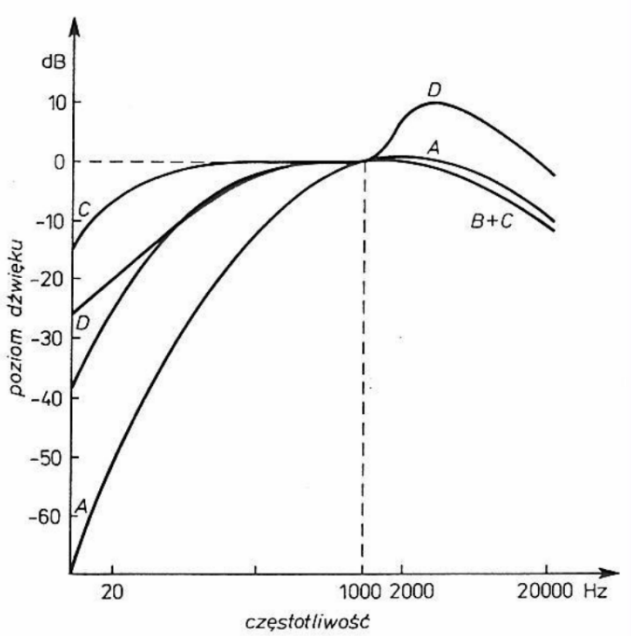

Figure 2. Acoustic correction filters

The A correction filter adjusts the measuring characteristics of the device to the ear sensitivity characteristics in the range of low volume levels (0-55 phons), B filter in the medium range (55-85 phones), and filter C, for high loudness levels, above 85 phons. For particularly high sound levels, e.g. aircraft noise, D curves have been introduced.

Noises not exceeding level of 35 dBA are harmless to health but sometimes could be annoying. Sometimes the sounds made by nature are beneficial.

Noises with the level of 35-70 dBA have a negative effect on the body, causing nervous system fatigue, lowering the sensitivity of eyesight, hindering speech intelligibility, communication, and adversely affecting sleep and rest.

Continuous noise exposure with a level of 70-85 dBA has a negative impact on work efficiency and is detrimental to health. There is a decrease in hearing, headaches, and nervous disorders.

Noises with levels in the range of 90-130 dBA are dangerous to the body, causing numerous disturbances. Noises with levels higher than 130 dBA generate vibrations of some human internal organs, causing their disease and destruction.

Noise affects speech intelligibility. In the noise of the level:
0 - 30 dB you can communicate in a whisper,
30-55 dB with a normal voice,
60-75 dB with a raised voice,
80-95 dB conversation is very difficult,
95-100 dB, you can only communicate by shouting,
above 100 dB, verbal communication is impossible

3. Vibration measures and levels

There are three most popular evaluation methods: root-mean-squared method (RMS), vibration dose value method (VDV) and maximum transient vibration value method (MTVV). The RMS method is called “basic method” in the [6] standard, while VDV and MTVV methods are called additional methods. These two methods, especially VDV is recommended as additional methods in high crest factor value situations.
RMS method averages acceleration values in duration time:

$$a_w = \left[\frac{1}{T} \int_0^T a_w^2(t) dt \right]^{\frac{1}{2}} \tag{1}$$

where: aw(t) – is weighted acceleration as a function of time [m/s2], T – is the duration of measurement [s].
MTVV method also averages acceleration values but is more sensitive for occasional shocks and transient vibration by using a short integration time constant:

$$a_w(t_0) = \left[\frac{1}{\tau} \int_{t_0-\tau}^{t_0} a_w^2(t) dt \right]^{\frac{1}{2}} \tag{2a}$$

$$MTVV = \max[a_w(t_0)] \tag{2b}$$

where: τ – is the integration time for running averaging, is recommended to use τ = 1 s, t0 – is the time of observation (instantaneous time).

VDV method is the best for peaks because it uses fourth power instead of the second power as is used in RMS and MTVV:

$$VDV = \left[\int_0^T a_w^4(t) dt \right]^{\frac{1}{4}} \tag{3}$$

In the measurement practice of the influence of vibrations on people, the root mean square values of the accelerations are presented in the 1/3 octave bands. As a result, information is obtained not only about exceeding the threshold values, but also about the frequency band in which this exceeded occurred. This is particularly useful at the building design stage, because you can then "tune in" the structure of the ceiling or even the building in such a way that exceedances in individual bands do not occur. RMS method seems to be the most useful method. The best additional method to assess the influence of vibrations on people in buildings, when there is a peak in the recorded signal, is the VDV method.

Threshold of vibration (see Figure 3) are the basis for creating comfort level by multiplying them by factor “n” given for example in standards [6-7].

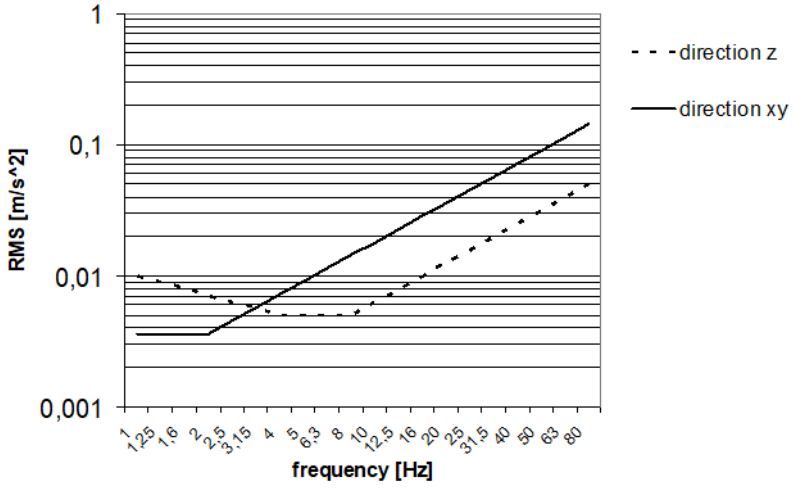

Figure 3. Thresholds of vibration

4. Noise and vibration protection in environmental regulations

The main legal act that defines issues related to environmental protection in Poland is the Environmental Protection Law of 2001 [8]. In art. 3 it was stated, inter alia, that whenever the Act mentions:

4) emissions - it means the direct or indirect, as a result of human activity, introduced into the air, water, soil or soil:
a) substances,
b) energies such as heat, noise, vibration or electromagnetic fields.

49) pollution - it is understood as emission that may be harmful to human health or the state of the environment, may cause damage to material goods, may deteriorate the aesthetic values of the environment or may conflict with other, justified ways of using the environment.

Thus, in the light of the aforementioned Act, noise and vibrations are the emission of pollutants into the environment, i.e. all requirements relating to the emission of pollutants also apply to the emission of noise and vibrations.

Another legal act that draws attention to the need to protect against noise and vibrations is the Construction Law [9]. In Art. 5 it is written:

"A construction object with related construction equipment should be designed and built in a manner specified in the regulations, including technical and construction regulations, and in accordance with the principles of technical knowledge, taking into account the expected period of use, ensuring:

1) compliance with the basic requirements concerning:
a) construction safety,
b) fire safety,
c) safety of use,
d) appropriate hygienic and health conditions and environmental protection,
e) protection against noise and vibrations,
f) energy savings and adequate thermal insulation of partitions".

Noise and vibration are also mentioned in [10]. In § 11 it is said that:
"The building with rooms intended for people should be constructed beyond the range of threats and nuisance specified in separate regulations, while it is allowed to erect buildings within this range provided that technical measures are used to reduce the nuisance below the level established in these regulations or to increase the building's resistance to these. threats and nuisance, if it is not inconsistent with the conditions established for areas of limited use, specified in separate provisions.

2. The nuisance referred to in par. 1 includes in particular:
1) harmful radiation and the influence of electromagnetic fields,
2) noise and vibrations (vibrations),
3) ..."

COUNCIL DIRECTIVE 97/11 / EC of 3 March 1997 amending Directive 85/337 / EEC [11] on the assessment of the effects of certain public and private projects on the environment specifies the scope of information that should be provided in an appropriate form by the Contractor:

"1. Description of the project, including in particular:
- description of the physical characteristics of the project and the land use requirements during the individual construction and operation phases
- description of the main features of the production processes, for example, type and quantity of materials used,
- assessment of the type and quantity of expected residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc.) resulting from the operation of the proposed project."

Directive 2002/49 / EC of the European Parliament and of the Council of 25 June 2002 [12] relating to the assessment and management of environmental noise is setting new ones approach to noise pollution in the regulations of the European Union. Earlier Community legislation focused primarily on the sources of noise, however because it has been proven that the environment is continuously affected by many emitting sources noise, it was necessary to change the approach and recognize environmental noise as an effect the impact of multiple emission sources that raise the level of noise pollution to values harmful to health and the environment. In the aforementioned Act, "noise pollution" was defined as "occurrence in an environment of noise or vibration emanating from any source and constituting nuisance or threat to the health and life of people, their activities or any property, including those that interfere with the natural or significant sounds of nature affecting the natural environment "

The Annex to the Commission Directive defines common methods for assessing noise and vibration [13]. The assessment methods provided for in the Annex to this Directive are to be adopted in accordance with Article 5 thereof. 2 clause 1 until 31 December 2018 at the latest, while Member States may continue to apply until then assessment methods previously adopted at national level in accordance with Art. 6 sec. 2 of Directive 2002/49 / EC [12].

Despite the fact that in many countries, including Poland, the phenomena of noise and vibration are analyzed separately, there is currently a goal of a joint assessment of these two phenomena. This is reflected, for example, in one of the EU directives [14].

5. Conclusions

This article presents the problem of noise and vibrations in terms of environmental protection. of course, the problem of environmental protection is a much broader topic [15-16], but this article focuses on one of its aspects, which is often overlooked by researchers, the vibroacoustic influences.

The first part of the article describes the problems related to noise and vibrations as unwanted stimuli that may adversely affect the human body. Then the most frequently used measures to assess the impact of noise and vibrations on the human body are described. the essence of the article is the collected and described legal acts related to the protection of the environment, which talk about the need to protect against noise and vibrations. It is a summary that is hard to find in contemporary literature.

As it can be seen in this article, even though both noise and vibration are considered as pollutants, there are completely different methods of their assessment. Vibration exposure is described using physical quantity - mechanical vibration accelerations, and noise exposure is described by decibels which are not physical quantity by itself, but are only comparative scale. Of course inside sound level formulas acoustic pressure exists which is physical quantity, but is not used directly in noise exposure assessment. The only thing in common is that both VDV(eventually RMS) method and sound level exposure are used to define safety threshold levels or annoyance threshold levels. But their mutual interaction is not described in current legislation. The correct definition of the measurement methodology, as it was done in the paper, allows for the correct design and implementation of noise and vibration protection, such as acoustic screens, anti-vibration barriers in the ground, or various types of vibro-isolating spacers in the source of vibrations.

Acknowledgment

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