UDC: 534; 331.45
OECD: 01.03.AA; 10.63.49

Assessment of non-hazardous low-frequency noise exposure

Behar A.
Research associate, Ryerson University, Toronto, Canada

Abstract

Low Frequency Noise (LFN) is a phenomenon found in the environment and generated naturally (volcanoes, earthquakes) or as a result of human activities (large engines, windmills). When at high levels, it causes complaints mainly of annoyance, but also of pressure in the chest or others. The assessment of LFN has been a problem, resulting several methods, adopted in different countries and jurisdictions. The two most popular assessment methods are based in measurement in dBA and on the difference dBC-dBA. This paper analyzes their accuracy and point out the needs for research into the variables compounding the annoyance from LFN.

Keywords: noise, hazardous noise, safety, low-frequency noise, noise exposure.

Оценка воздействия неопасных низкочастотных шумов

Бехар А.
Научный сотрудник, SMART Lab, университет Райерсона, г. Торонто, Канада

Аннотация

Низкочастотный шум (НЧ-шум) - это явление, встречающееся в окружающей среде и генерируемое естественным путем (вулканы, землетрясения) или в результате деятельности человека (большие двигатели, ветряные турбины). При повышении уровня он вызывает жалобы, в основном на раздражение, но также и на давление в груди или других органах. Оценка НЧ-шума представляла проблему, в результате чего появилось несколько методов, принятых в разных странах и юрисдикциях. Два наиболее популярных метода оценки основаны на измерении в дБА и на разнице дБН-дБА. В данной статье анализируется их точность и указывается на необходимость исследования переменных, усугубляющих раздражение от НЧ-шума.

Ключевые слова: *шум, опасный шум, безопасность, низкочастотный шум, воздействие шума.*

Introduction

Most noises found in every-day life are of broad band nature, with their energy quasi-uniformly spread across the spectrum. Their measurement and assessment is relatively easy and there are commonly accepted standards on how to do it. There are, however, situations, where most of the energy is concentrated in the lower end of the audible spectra, the so called low frequency noises, where the assessment presents problems, not yet solved. That is the reason for the existence of different methods adopted by different countries [1]. This paper is to address the assessment process, focusing in particular on the dBC-dBA method.

E-mail: albehar31@gmail.com (Behar A.)

1. A little bit of history

In 1933 Fletcher and Munson developed a set of equal-loudness contours using pure tones conveyed via headphones [2]. Contours indicate sounds perceived as being of equal loudness when presented at different frequencies. They show that the loudness is strongly dependant of the frequency of the tone as well as of their sound levels. Contours were later revised by 1956 Robinson and Dadson [3], using loudspeakers in an anechoic environment. They obtained a new series of curves believed to be more accurate. The curves became the basis for an ISO Standard that was considered definitive until 2003. Then ISO revised the standard [4] on the basis of further research conducted by different research groups around the world.

Originally, Sound Level Meters were intended to measure the loudness of sounds. From the first beginning, they introduced a simplification to the equal-loudness contours using three filters: A, B and C. The first, A, was intended for sound levels below 40 dB. C was intended for those above 70 dB, and B for all of those in between. Later on, studies found high correlation between hearing loss and sound level measurements of workplace noise performed using the A filter (in dBA)[5]. Consequently, the use of the filter "A" became universal for assessment of workplace noise. Other studies found correlation between dBA and annoyance for environmental noise in general, increasing its use even further. Finally, with the use of NRR [6] for the measurement of the attenuation provided by hearing protectors, the "C" weighting also came into widespread use. The three curves are specified in an IEC Standard [7].

These curves were also used in the first American standard for sound level meters [8]. This ANSI standard, later revised as ANSI S1.4-1981, had the B-weighting incorporated, together with the A and C-weighting curves. B-weighting has since fallen into disuse up to the point that many SLMs do not have it at all.

2. Why dBA

2.1. Hazardous noise

In the field of Industrial Hygiene, noise is considered as hazardous, when it affects the organ of hearing, the ear, causing hearing loss. As a stress agent, we know that it may generate other effects such as annoyance, sleep interference, speech interference etc. There can also be effects of noise exposure on the nervous system, the cardio-vascular system, and other body systems. However, noise that may lead to effects on systems beyond the ear are generally not taken into consideration in noise standards.

As a result of laboratory and epidemiological studies, there is an almost universal consensus that noise exposures in excess of 85 dBA (8hs/day, 5 days/w, 40 years) may cause hearing loss. This is well documented in the ISO Standard 1999 [9].

A noise assessment is done in two steps. The first consists in the measurement of the noise exposure. It is performed using preferably an integrating sound level meter or a dosimeter, set up to measure in dBA and Slow [10]. The second step requires comparing the measured result to the above mentioned limit of 85 dBA. If the limit is exceeded, then the noise is considered hazardous.

What is not often mentioned is that this criterion applies to narrow as well as broadband noises, i.e. noises where the energy is spread uniformly along the audible spectrum. With few exceptions, industrial noises tend to be broadband.

2.2. Non-hazardous noise?

There are no uniform criteria for non-hazardous sources of noise. There are guidelines, bylaws and local regulations that vary among countries and among local authorities. One of the reasons for this situation is the complexity of the problem. When dealing with non-hazardous noises, there are many variables that must be considered beyond the sound level.

Some of these variables pertain to the noise itself, such as:

- Frequency content
- Duration
- Impulse characteristics
- Special characteristics of the noise that make is especially irritating

Some of these variables pertain to the context within which the noise occurs:

- Time of the day the noise occurs
- History of previous exposure to the noise in question

Other variables may be considered psychological reactions to the intruding noise[1], such as finding it:

- unnecessary or unnecessarily loud
- a threat to personal health and safety
- a threat to economic investment
- beyond the affected person's control

Whoever has had dealings with annoying noise has many anecdotes to tell about situations where a loud noise was dismissed as such on the bases that the person causing it was a “nice” person. In other situations, the noise was considered intruding just because the person responsible for the noise and the person affected by the noise were not on the best of terms with respect to their personal relationship.

A literature analysis relative to noise exposures that can disrupt sleep, communication, task performance, and productivity was prepared for the World Health Organization by Berglund and Lindvall [11]. Some conclusions are as follows: Noise measures based only on energy summation are inadequate for the characterization of most noise environments, particularly when health assessment and prediction are concerned, and durations of the measurements depend upon the activities involved. One must measure the maximum values of noise fluctuations, preferably combined with a measure of the number of noise events, and assess whether the noise contains a large proportion of low-frequency components. For homes, recommended guideline values inside bedrooms are 30 dBA for steady-state continuous noise and 45 dBA (Fast Max) for a single noise event. To prevent a majority of the population from being seriously annoyed during the daytime, the equivalent level from steady continuous noise in outdoor living areas should not exceed 55 dBA. During the night, outdoor levels should not exceed 45 dBA so that people may sleep with bedroom windows open. It is recommended that in schools, the level should not exceed 35 dBA during teaching sessions. In hospitals during nighttime, the recommended value is 30 dBA.

It has to be pointed out that too low ambient noise level may annoy some people, as unwanted sounds are not masked. By the same token, such an environment may be highly distracting for employees in an office.

Clearly, establishing limits for non-hazardous noise is a very complex task to be entertained. Annoyance will always be a problem, no matter how well other effects are controlled.

3. Problems with low-frequency noise (LFN)

There is no definition on low frequency noise. The term applies generally to noise with most of the energy contained below 200Hz. ANSI does define Infrasound as “sound at frequencies less than 20 Hz." [12].

[1] It is worth remembering the old saying: music is what I do and noise what my neighbor generates...

LFN does not affect hearing[2] in general, but it can be quite annoying. Because of its physical characteristics, it does not decay easily with distance and travels distances without attenuation by ground. Furthermore, sound barriers, natural or artificial, are mostly ineffective because of the diffracted energy that goes "over" or "around" the obstacle. Transmission loss of materials decays with frequency. Therefore, low frequency noise penetrates easily through walls into enclosures and living places. To make matters even worse, because of the long wavelength comparable to the size of rooms and offices, low frequency noise can generate standing waves with clearly audible "hot spots" that are highly annoying and exceedingly difficult to control.

The usage of the A filter under-values the impact of low frequencies. For example, a sound of 100 Hz is attenuated by almost 20 dB, while a sound of 50 Hz is attenuated by 30 dB. The effect of this attenuation, especially in the low frequencies range below 200 Hz, is that a noise with mainly low frequencies content (such as the one from a large truck engine) shows a low reading on a sound level meter, even though an observer can perceive it as an impressive roar. This author remembers clearly measuring 35 dBA in a workplace that was perceptibly shaking because of the presence of several looms. The noise was felt in the chest of the observers, but remarkably, there was no consequential measurement that could be obtained using the sound level meter.

To summarize, when measuring low frequency sound sources using the dBA weighting, readings tend to be low, even when the noise is highly annoying. In view of this problem, several attempts have been made to improve the assessment of LFN. The objective has been to obtain a relatively easy way to measure the noise with a result that the measurement correlates with the subjective feeling experienced by those exposed to the noise.

Probably the most popular method to come along is the C-A method. It is relatively easy to perform using a conventional sound level meter, since it simply requires data points obtained measuring in dBA and dBC.

4. The dBC-dBA as a descriptor for low frequency noise (LFN)

This method consists of the following:

a) measuring the noise in dBA and dBC

b) using the difference between both readings to characterize the noise as LFN, A large difference between both readings will indicate that the noise has a large low-frequency content. (Figure 1 shows both curves. It can be seen how difference between both increases as the frequency decreases).

c) If the noise is found to be LFN, a penalty is applied to the measured dBA value[13].

As an example, let's suppose a jurisdiction has a noise limit of 50 dBA. Suppose also that a noise level of 45 dBA is measured that would be considered acceptable ($<$50 dBA). However, a difference dBC-dBA of 15 dB was also measured. Then, as per the jurisdiction's existing bylaw, a 10 dB penalty is applied to the measured level of 45 dBA, resulting in 55 dBA. This exceeds the limit of 50 dBA and the noise is considered inacceptable.

The above simple example of applying the dBC-dBA rule shows that there is a need to establish:

a) A baseline sound level, in dBA (50 dBA in the above example)

b) A difference dBC-dBA that classify a given noise as "low frequency" (15 dB) and

c) The size of the penalty to be applied to the measured noise (10 dB). This penalty, obviously, should be proportional to the dBC-dBA difference.

In other words, the proposed descriptor would ideally define three parameters before

[2]It may if there was enough energy in or around 150 Hz, that could affect hearing in that region which would affect voice pitch, leading to problems with voice identity/emotion/etc...

being adopted as a replacement to the existing dBA. To determine the values of those parameters, there is a need for psycho-acoustic studies to be performed over statistically significant samples of populations, studies that we are lacking at present.

A proposal to replace the measurement in dBA by an improved dBC-dBA descriptor [14] has been made recently. The proposal consists of averaging the "A" filtered sound levels of the 1/3rd octave bands between 16 Hz and 200 Hz and qualifying the noise as "low frequency" if the C-A difference is equal or larger than 15 dB.

This proposal includes the need of frequency analysis with the claimed advantage of classifying as "noisy" situations that otherwise will not be recognized as such. However, on top of the added complexity required in this new measurement technique, there is still the need for defining and justifying the parameters mentioned above.

Conclusions

In this paper we have focused on annoyance from non-hazardous, low-frequency noise and the difficulties in its assessment. The use of dBA is definitely not acceptable, unless different limits are set, as per ref [1] The dBC-dBA method has also been developed without defining and justifying the critical parameters mentioned above to provide support for any penalties applied to measured noise levels.

We see a need for psycho-acoustic researches to be conducted to define and justify these parameters. In particular:

a) Laboratory studies assessing annoyance from noise with different low-frequency content, both artificial or real-life (occupational, windmills, transit) and

b) Surveys in real-life situations including measurements and questionnaires.

Acknowledgments

The author wants to thank Geoffrey Loeventall for earlier analysis and suggestions and Frank Russo, SMART Lab., Ryerson University for reviewing the final version of the paper. Thanks are also given to F. Copelli, SMART Lab Manager, for reviewing and helping to format this paper.

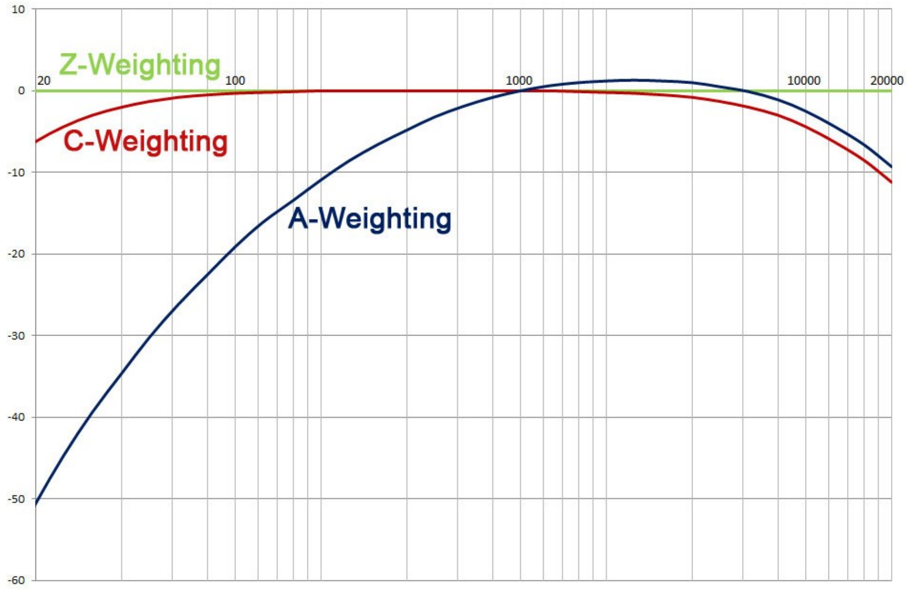

Fig. 1. A and C frequency weighting curves (By Acousticator - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=46539432)

References

1. Broner N. A. Simple Criterion for Low Frequency Noise Emission Assessment., Journal of Low Frequency Noise, Vibration and Active Control Volume: 29 issue: 1, page(s): 1-13.ion & Active Control.

2. Fletcher, H. and Munson, W.A. "Loudness, its definition, measurement and calculation", Journal of the Acoustical Society of America 5, 82–108 (1933).

3. Robinson D. W. et al., "A re-determination of the equal-loudness relations for pure tones", Br. J. Appl. Phys. 7 (1956), pp.166–181.

4. International Standard Association ISO Standard 226:2003. Acoustics – Normal Equal-Loudness-Level Contours (2003).

5. Burns, W. Noise and man, John Murray (1973)

6. American National Standard Institution ANSI/ASA S12.6-2016: Methods For Measuring The Real-Ear Attenuation Of Hearing Protectors

7. International Electrotechnical Commission IEC 61672-1:2013: Electroacoustics - Sound level meters - Part 1: Specifications

8. American National Standard Institution ANSI/ASA S1.4 -1971: Sound Level Meter.

9. International Organization for Standardization ISO 1999 (2013): Acoustics - Estimation of noise induced hearing loss.

10. Canadian Standard Association (2018) CSA Standard Z107.56-18 Measurement of noise exposure.

11. Berglund B. and Lindwall T. (Eds). (1995) Community Noise (Archives of the Centre for Sensory Research, Vol. 2 Issue 1). Stokholm University, Stockholm, Sweden.

12. American National Standard Institution ANSI/ASA S1.1-2013: Acoustical Terminology.

13. Energy Resources Conservation Board. Directive 038 (2007): Noise Control. Calgary (Alberta), Canada.

14. Montano W.A. Low-frequency noise and infrasound are underestimated by dBA measurement. After 80 years it is necessary a LFN descriptor for rating its annoyance. Noise Theory and Practice (2020), Vol 6, No1. 7-29.