Annoying low level sound

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ABSTRACT

A very specific, low level sound from an unknown source, persisting over months, may drive a person crazy, while known sounds are tolerated. Usually, a person living in a very quiet apartment is affected. Although each case is different from the other, it would be well worth to draw some scientific attention to the phenomenon. The presentation will focus on practical aspects on how to help these people. The first question to be answered is: Is there any medical indication, e.g. some sort of Tinnitus, or is the annoyance caused by real sound or vibration from a technical source? If it looks like the annoyance being caused by a technical source, the search with acoustical means is usually very time consuming. Search strategies will be discussed. If the search fails, masking of the annoying sound by some broadband noise from a loudspeaker or a well may provide some relief.

INTRODUCTION

This paper deals with a specific aspect of the conference topic “noise as a public health problem”: it reports about individuals annoyed by specific low level sounds. Although these people represent a very low fraction of the population, they do suffer from noise or vibrations that other people hardly notice. The focus here is how to alleviate the specific situation of an individual person.

For environmental agencies, the question on how to handle low noise complaints is different from the situation reported here about individuals. Some publications covering primarily the question on how to handle low noise are: a survey on low noise situations in Germany by the Umweltbundesamt in 2014 [1], the DIN 45’680 “tieffrequente Geräuschimmission”[2], or the recommendation of the Robert Koch-Institut, Germany [3].

The person-centred approach taken here has a long tradition at the scientific institution Empa in Switzerland [4], [5], [6]. The focus here is how to alleviate the specific situation of an individual person. The discussion of noise limits is irrelevant in this context, because the person is annoyed as long as the sound is hearable or the vibration is felt. For the judgement of audibility one has to consider, that a few percent of the population have a hearing threshold up to 10 dB lower than average.

The start of an investigation is complicated by the fact, that the complaints are usually diffuse and the annoying sound is seldom obvious for the acoustician. Therefore, it is an advantage if the first investigating person is a medical doctor. If it turns out, that there might be a physical source for the problem, the annoyed person is asked to make precise observations, providing the acousticians with hints on the character of the sound or vibration. First measurements with one-third octave of with narrowband (FFT) analyses may disclose the character of the source. Finally, if a device or an installation has been identified as a possible source, the switching off and on will show, if the source of the annoyance has been found. Any improvement will be made according to building acoustic state of the art by decoupling structure borne sound transmission. However, in many cases the search fails or a reduction of the immission is impractical. In these cases an option is to add low level broadband noise to living rooms in order to mask the annoying sound.

PART 1: GETTING HOLD OF THE ANNOYANCE

Finding a common language

Although each case is individual, the cases also have common ground. The perceived sound is annoying the person very much. Usually persons live in a very quiet area. The annoyance by a sound is typically established over months and the complaints are usually getting quickly complex, often with sleep disorder and exhaustion. Other, known - and louder - sounds e.g. from house appliances are no problem. Sounds at frequencies below about 25 Hz may be reported as unpleasantness or vibration rather than as sound. Since the concerned person perceives the sound being caused by a technical source, added unsettledness arrives, if not all people coming into the apartment do also perceive the sound. Some person consult their generalist, some contact directly an environmental office, many persons have got through a long odyssey. In Switzerland, the “Ärztinnen und Ärzte für Umweltschutz” have implemented an environmental counselling duty for person with environmental related symptoms [7], [8]. Their experience shows how crucial it is, that concerned persons not only consult their general practitioner, but in a second step also the otorhinolaryngologist (ear-nose-throat doctor). This doctor performs audiometries and assesses profoundly possible medical causes of Tinnitus, but he or she also discusses the possibility of an external acoustic source [9]. If the generalist and otorhinolaryngologist assess an external source as possible, an exploration by an acoustician is reasonable. Such an interdisciplinary approach is well suited to prevent long odysseys and further chronic annoyance.

An environmental questionnaire could be a useful tool to assess the characteristic of the sound and serve as basis for a common language between the concerned person, the medical doctors, and the acousticians.

Involving the annoyed person as an expert

The affected person itself knows best the disturbance. Therefore, first investigations need no instruments. A careful investigation is needed to find a common language on what is annoying and what is not. He or she is the expert to answer the following questions:

- “Do you hear it everywhere, also outside the house at quiet places?” If the answer is yes, it is likely to be a Tinnitus and there is no need for an acoustic investigation.
- “If you plug your ears, do you still hear it?” If the answer is yes, it is likely to be a Tinnitus.
- “Do other people also hear the noise and if so, are you sure that they hear the same noise than you?” If yes, the possibility for a successful measurement rises.

- “Does the noise depend on the location? (specific place in the room, specific room in the apartment, louder in the heating room, ..)” The answer may give hints to technical devices, sound borne transmission paths, and standing waves in a room.
- “Are there any temporal patterns? (Only during working hours, only after 22:00, only in winter / summer) The answer may give hints to industrial devices or house appliances.
- “What is the character of the disturbance? (single sound at high/medium/low frequency, beat, broadband noise, infrasound i.e. undefined nausea, vibrations)”. An aid is using a sound generator and a headset. The generator is set to different frequencies and waveforms and the annoyed person reports, if the generated sound is similar to the annoying sound.

Measurements

If there is a possibility that the annoyance is caused by sound or vibration, the acoustician may start with measurements.

A microphone may be positioned at that place in the room, where the annoyed person hears it best. For sounds below 100 Hz, attention has to be paid to possible room modes. In doubt, the microphone may be placed in a corner of the room. For not disturbing the measurement, the microphone is connected with a long cable to the sound level analyser, which is positioned outside the room, with the door closed. As a first test, the measured signal may be amplified e.g. by 30 dB and presented by a headset to the annoyed person with the question: Does she or he hear in the amplified signal the annoying sound? The headset used should be a closed type with minimal sound emission in order to avoid acoustic feedback to the microphone. For low frequencies, the lower frequency limit of the headset (20 .. 30 Hz) must be kept in mind. For the microphone, a ½” type, class 1, is usually sufficient, as the linear levels at low frequencies are rather high, i.e. sufficiently higher than the noise floor in the 1/3-octave bands of the microphone.

If the annoying sound is not heard with the headset, the situation becomes complicated. Is it after all Tinnitus, or does the “logic of invisibility” apply? That is, if the measurement fails, this does not mean that there is no annoyance, but only that the disturbance was either not active during the measurement period or that it was not identified. In this case, further measurements might be extended over longer periods of time, using multichannel recordings with the most sensitive sensors. For sound measurements “low noise microphones” may apply and for vibrations seismic accelerometers of e.g. 10V/g sensitivity and integration to velocity. Further, periodic audio recordings are needed. Therefore such investigations become very time consuming and expensive.

Long-time measurements may be reviewed by looking for specific patterns in the 1/3-octave level-time graphics. If a specific event was identified, the corresponding AC-recording may be presented to the annoyed person with the question: Is that the sound annoying you? – And often, this it is not the case.

Analysing the measurements and comparing with thresholds

As an example, in the Swiss building Code SIA 181 [10] the stringiest noise level is 25 dB (A) for noise immission from house appliances outside the own apartment. The levels discussed here are usually much lower. The question arises: what is hearable? For the low levels discussed here, the A-weighted sound level is inappropriate. The standard DIN 45’680 ”Messung und Bewertung tieffrequenter Geräuschimmissionen in der Nachbarschaft” [2] proposes to compare the 1/3-octave band levels with the hearing threshold. The recent

investigation on equal loudness [11] proposes lower values for the hearing threshold, taking into account the data from ISO 28'961 on statistical distribution of threshold [12]. See figure 1. A small fraction of the population may hear tonal sounds up to 10 dB below the usual "hearing threshold".

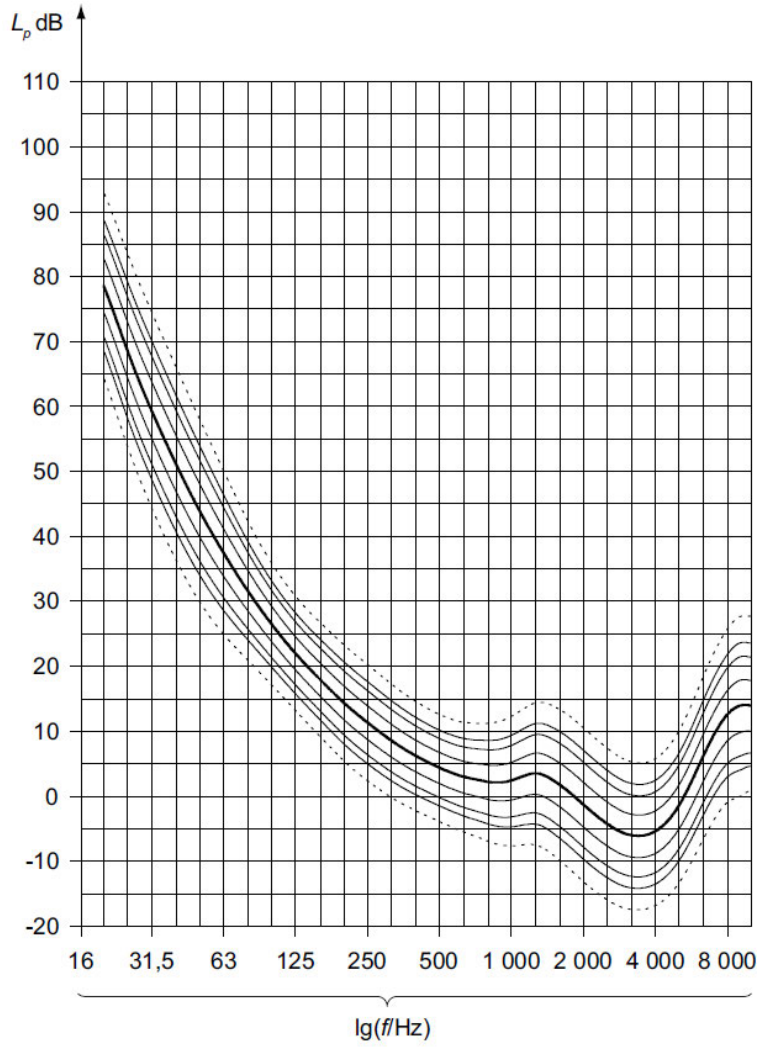

Figure 1: Percentile curves of hearing thresholds according to ISO 28'961, Fig. B1. From top to bottom, the curves are those for P99 (dotted), P95, P90, P75, P50 (bold) P25, P10, P5 and P1 (dotted). L_p: sound pressure level; f: frequency

If the 1/3-octave band evaluation shows no conclusive results, a narrowband (FFT) analyses may help to identify pure tones e.g. at 49.7 Hz from an electric motor. Modern pumps are electronically regulated, and their rotational speed may vary. In most situations, the annoying sounds are amplified by resonances in structures and in the room. Thus, the annoying sound may be heard one day when the pump is operating at a specific speed exiting resonances, and may be not heard when the pump is operating at slightly other speeds. The statement of the annoyed person to the acoustician: "Yesterday it was horrible, but as you are here today it is nothing" may be true and can only be verified by long-term measurements.

For vibrations, the threshold is discussed controversially, e.g. in the congress papers on Environmental Vibrations [13] or in the book by Griffin [14].The sensation depends on the direction of the vibration and the position of the body. For people living in buildings, ISO 2631-1, Annex C3 [15] proposes a weighted acceleration of 0.015 m/s^2 as perception

threshold. The new VDI 2057-1 [16] and 2057-3 [17] also rely on acceleration to specify acceptable levels at working places. The German DIN 4150-2 [18] uses velocity as input parameter. When dealing with velocity, an orientation on sensory threshold may be provided by the old edition of VDI 2057(1963), where a value of about 0.1 mm/s is reported for people in buildings and for vibrations in the range from 10 to 100Hz.

Structure borne vibrations radiate sound in the room, depending on wall material properties and on room resonances. For frequencies in the audible range, the emitted sound from walls or floors is generally better heard than the vibrations are felt. Thus, vibrations usually must only be considered for frequencies below about 30 Hz.

If a well identified sound (or vibration) has been found to be the cause of the annoyance, the search of the source may start.

PART 2: IDENTIFYING THE SOURCE

The FFT spectrum at a resolution of e.g. 1 Hz or finer may disclose the type of the source. If it is a single peak, it may be generated by a rotating machine.

Measurements (preferably structure borne vibrations) at various places (bed room, living room, cellar, outside the house) may give a hint where from the sound may come.

If there are specific time patterns observed, e.g. annoyance only in winter, only during working hours or only at night, this may help to find the appropriate source.

When the annoying sound disappears after switching off a possible source, the source is finally found.

PART 3: ALLIEVATING ANNOYING SOUNDS

Once the source of the annoyance has been identified, the standard acoustic instruments for sound reduction may be used: at the source by replacing a defective device by a quieter one, or at the transmission by suppressing the coupling of vibrations to the ground or walls by resilient mountings etc.

If measures at the source or on the transmission path are impractical, one possibility is to establish a masking in the room, by generating an additional, continuous sound. In rare cases, the active sound cancellation may be considered.

CONCLUSIONS

Low level sounds persisting over months may drive individual person crazy, while everyday noise from traffic, humans and machinery is accepted. These people suffer and it is well worth giving them support, primarily medical, and if it turns out to be a physical problem, from the part of acoustics. The authors made good experiences with the procedures described here. It is crucial that the annoyed person is not redirected from one government agency to another, but quickly finds an environmental counselling duty. A challenge is that many cases are complex, time consuming and hence expensive. Therefore it is important, that the experts involved have profound experience in the specific human and technical topics.

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