inter.noise 2010 noise and sustainability
13-16 June 2010 . Lisbon . Portugal
www.internoise2010.org

LOW LEVEL INTRUSIVE NOISE AND LOW FREQUENCY NOISE.

Martin van den Berg

Affiliation: Ministry of Housing, Spatial Planning and the Environment
e-mail: Martin.vandenberg@minvrom.nl

Abstract
Low frequency noise has always been treated in a special way, and the effects were sometimes blown up to mythical proportions. Objective studies at everyday levels were however unable to substantiate these claims, but some peculiar things keep coming up. One thing is that LF-noise just over the hearing threshold may cause a lot of annoyance, while it is assumed that this is not the case for noise with a regular frequency distribution. Little however is known about the annoyance of low level intrusive noise, but one very thorough study and anecdotal evidence points to a more general phenomenon.

Keywords: Low level, low frequency, annoyance.

1 Introduction

There is little doubt that under the flag “low frequency noise” (LF-noise or even LFN) quite a few diverse nuisance problems were placed. The myth around LF-noise reached a summit in the 1970’s, but was elegantly debunked by Leventhall [1]. Apart from the sensational newspaper headlines that he quoted, the proof that the concept of deadly sound rays penetrated even deeper into the public domain can be found in the famous comic by Hergé, “Tintin e L’affaire tournesol”[2]. Although in the album it is indicated by “ultrasound”, it is made clear that high power sound waves can kill and destroy cities (Herge, 1956). Another example in the same popular “literature” is the “Gaffaphone”, invention by Gaston Legaffe [3] and capable of total destruction of the office building where Gaston worked.

A study by Moorhouse [4] on complaints classified as “low frequency noise” provided the following fascinating list of descriptions:

- ‘like a car ticking over’;
- ‘a distant hum’;
- ‘like a refrigerator building up again after the door has been opened and closed’;
- ‘like a central heating boiler’;
- ‘a whine like a jet engine or turbine’;
- ‘a whistle’;
- ‘a short beat and a long beat’;
- ‘like a lorry with the engine going’;
- ‘like a meter winding down’;
- ‘like a spin dryer’;
- ‘like being in a microwave’;
- ‘like a kettle warming up’;
- ‘like aircraft high overhead’;
- ‘a deep roar’;
- ‘like a compressor unloading’;
- ‘like emerging from a tunnel’;
- ‘like fishing boats going to sea at night’;
- ‘like air roaring up a chimney’.

Although some might fit a LF sound source, part are certainly not, and most seem to refer to other characteristics. This hints at a misclassification between psycho-acoustic categories and common understanding, but perhaps something more fundamental.
In general the LF-cases fall in the category “low level” noises, sometimes so low that not all people are able to hear it. The not always outspoken assumption is that as these levels are below the levels that causes annoyance for most other noise sources, so the LF character should be blamed. But from the above descriptions it appears that not-LF noises can be disturbing as well at low levels. There is at least one well documented source that is highly annoying at low levels but is not – particularly- low frequency: wind turbine noise. Some dose effect relations seem also to indicate that annoyance occurs at relatively low levels. Thresholds for aircraft noise annoyance in the newer studies tend to 30-35 Lden, and there is lot of anecdotal evidence on mosquito, mice and music from neighbouring dwellings. The current approach is to assess the intrusive characteristics of these sounds in order to rank them according to their annoying potency. The questions is if this approach really leads to the correct ranking.

2 Differences between psycho-acoustic categorization and perception.

Describing sounds is not so easy. In a study into the effects of industrial noise Groeneveld [5], provided these interesting tables.

Table 1 expert and public judgement on impulsive noise in [4]

		Impulsive according to respondents		
		Yes	NO	total
Impulsive according to experts	Yes	102	150	252
	NO	36	172	208
	total	138	320	460

In the first row 102 respondents agreed with the acousticians that the noise was impulsive, but more (150) did not. Interesting is that in the inverse case (acousticians stating that is was not impulsive), less disagreed (36). Overall 60% agreement (yes/yes somewhat less then no/no)
The same outcome also for fluctuating noise in table 2:

Table 2 Expert and public judgment on fluctuating noise in [4]

		Fluctuating according to respondents		
		Yes	NO	total
Fluctuating according to experts	Yes	57	219	276
	NO	35	149	184
	Total	92	368	460

In this case only 44% agreement acousticians and respondents, yes/yes much less than no/no. Finding a physical description that fits the annoyance of a sound has proven to be very hard. Even with simple qualifications like impulsiveness and tonality there is not much agreement. When offending noises contain a number of special characteristics with different duration, it becomes an impossible puzzle to say which of the penalties may apply for which duration. A simple example is the everyday pub, where tonal noise (the music in the bar), impulsive noise (bottles in crates) and LF-noise (ventilator) may occur at the same time or in succession.

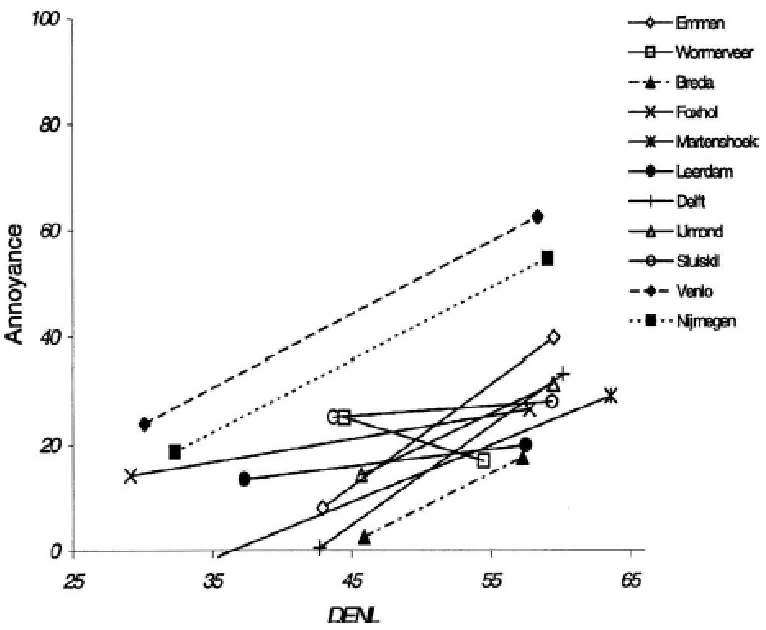

FIG. 1. Simple linear relationships between DENL and annoyance for the individual locations. Symbols are used for labeling purposes only and are no data points.

An interesting demonstration that the standard penalties do not always work comes from the dose-effect relationship study for industrial noise [6] .

In figure 1 dose-effect relations for different industries are plotted. The two upper lines (labelled Venlo and Nijmegen) are shunting yards. That seems to confirm the notion that the impulsivity is responsible for additional annoyance, as the shunting process leads to frequent collisions between train wagons. Subsequent analysis however showed that not the (perceived) impulsiveness of the signal contributes to annoyance, but the fact that this is a night time operation and the presence of vibrations. On the other hand there is the line labelled “Sluiskil”, which is a shipyard. Experts would consider a shipyard at least as impulsive as a shunting yard. The dose-effect relation however does not show a significant increase. Overall (over the whole of the survey) it was found that self defined “impulsiveness” contributed to annoyance, but if this relates to the corrected noise levels was not studied.

The same problem occurs when trying to assess the impact of LFN in the population. Table 3 deals with annoyance by vibrations as assessed in a random population survey in the Netherlands[7], and for most sources this gives an apparently reasonable answer. But the reply for air traffic vibration shows that there is more to it. As ground borne vibrations are negligible, this should be due to LFN (perhaps through making windows or other objects vibrate). It cannot be excluded that also for road traffic and railway traffic this is partly the case. By the way: noise annoyance for air traffic and railway traffic is almost the same as for vibration annoyance.

Table 3

Percent highly annoyed in the population by vibrations. Random surveys in the Netherlands[7].			
Vibration source	1993	1998	2003
Road traffic	6	5	5
Railway	1	1	1
Airtraffic	3	4	3

Industry	0	0	1
Construction sites	-	-	3

The conclusion so far is that it is not clear to what extent the LF- problems are really due to the LF–part of the spectrum or due to other characteristics of the signal.

3 Which factors contribute to annoyance of (low level) noise

Thorne[8] concludes in his elaborate thesis that a method can be constructed to objectively assess the intrusiveness of low amplitude sound, but that “however, the methodology is not predictive because intrusion is a human perception”. Basically he compares acoustical qualifications of a sound signal with musical terms. This helps to understand better what the acoustical descriptions stand for and leads to the construction of a complex method to rate “intrusiveness”.
In this method the Zwicker loudness is combined with measures for sharpness and for fluctuations. Central in this is the “Unbiased Annoyance” measure (UBA). It is not clear how this works out in practice to predict annoyance over a longer period. As shown by Thorne (2007), there is a large difference in reaction between groups with former experience with wind turbine noise and those without former exposure. It can be expected that the non-exposed group will eventually react the same as the exposed group, so this can also be regarded as a an experimental requirement to get reliable information. Another line of reasoning could be that a factor in the intrusiveness estimate is missing, namely the time factor: how do people react after long term exposure? Although a noise being intrusive is likely to help in making a sound annoying, the amount of time it can be heard is also very important.
Thorne[8] provides tables with calculated UBA values at different sound levels. Table 4 is an excerpt based on sounds with an LAeq of 40 dB.

Table 4. Unbiased annoyance scores adapted from [8]

Sound file	UBA-scores (rounded)
Amplitude modulated sample	10,1
Residential	8,9
Rural	8,7
Rock-music	8,7
Ambient + windpark-location 1	7,1
Ambient + windpark-location 2	6,8
Rough sample	6,3
Wind turbine	6,3
Artificial Wind turbine	5,9
Classical Music	5,4
modulated tones	5,3

This does not entirely coincide with the expected ranking of annoyance. The amplitude modulated sample is on top (this is really an awful sound), but wind turbines and classic music have low scores – lower than simple residential noise-, which is contrary to the high

annoyance found in wind turbines and with the penalties usually applied to music (if this is coming from an adjacent dwelling or pub).
Taken by itself, the annoying effect of fluctuating sound have been shown in various experiments, see [1], [4] and [9]. The magnitude depends on the amplitude depth. This effect partly explains the high annoyance of wind turbines, but although the existence of amplitude modulation has been shown, the depth is usually quite low. Pedersen[10] explains why wind turbines are more annoying than can be explained by the acoustic content:
The large impact of visual aspects in studies as regards resistance to local wind turbine projects (Wolsink 2005) shows that not only the noise, but also the prominent appearance of a wind turbine could be perceived as intrusive. The rotor blades of a wind turbine are furthermore almost constantly moving, attracting attention and making it difficult to ignore seeing the wind turbine. Inability to disregard visual and audible intrusion possibly adds to the impression that the environment is unsuitable for restoration.

4 Intrusive or LF

Looking back at the descriptions in section 1, it seems that special characteristics of the signal dominate. This might explain why Moorhouse[4] could relate only 3 of the 11 field cases to a specific part of the LF-spectrum. From chapter 3 it seems that also the particular characteristics of a sound by itself are not sufficient to predict annoyance. Does this apply then to LFN also?
In his overview of LFN Leventhall [1] states that… *At equal A-weighted levels, the noise dominated by the low frequency component was perceived as 4-7dB louder and 5-8dB more annoying*.
By itself this does not seem to explain the apparently high annoyance from some low frequency sources, although firm evidence for this is missing. Sometimes the elevated annoyance seems due to the fluctuating character of LFN, which occurs more easily with this type of sound.
Another physical characteristic of LFN may lead to a further underestimate, and that is the insulation of the facade. As the attenuation for low tones is less than for high tones, the levels inside have a higher LF content than levels measured outside. So far the levels discussed in this paper where on the subjects ear, but when translating the data to outside limit values, this should be taken into account.

5 Conclusions

Although psycho-acoustical descriptions of a sound may help to explain why a noise is annoying at low levels, it cannot be used as only measure to assess or predict the annoyance in the population from a particular exposition. Even exposing subject in laboratory settings may not get the rights results if the subjects had no previous experience with the source. Low frequency, fluctuations, tonality, impulsivity and duration all contribute, but the human interaction determines what the final impact is.
The bottom line is that fixed penalties should be handled with care, especially in situations where the offending sound contains a number of these special qualities, with different duration. If in doubt, preference should be given to results of dose-effect relations from field studies.

Acknowledgments

I thank the members of the Dutch Working Group on LF noise for the many productive discussions, and in particular Frits van den Berg who provided some vital clues.

6 References

[1] Leventhall, G. A Review of Published Research on Low Frequency Noise and its Effects, *DEFRA publications, contract nr EPG 1/2/50*, 2003, London, UK

[2] Hergé, *Tintin e L'affaire tournesol*, Casterman, Paris, 1956

[3] Franquin, *Des gaffes e des degats*, Dupuis, Bruxelles, 1970

[4] Moorhouse, A, ea, *Proposed criteria for the assessment of low frequency noise disturbance, DEFRA project NANR45*, London, UK

[5] Groeneveld, Y. Karakterisering en beoordeling van industrielawaai, IMG-TNO, Delft, 1981

[6] Miedema, H.M.E., Vos, H*. Noise annoyance from stationary sources: Relationships with exposure metric day–evening–night level (DENL) and their confidence intervals*, 334 J. Acoust. Soc. Am. 116 (1), July 2004

[7] Fransen, E.A.M. ea, *Hinder door milieufactoren en de beoordeling van de leefomgeving in Nederland. Inventarisatie verstoringen 2003*, RIVM, 2003

[8] Thorne, R. *Assessing intrusive noise and low level sound*, Massey University, 2007

[9] Vos, J. *Hinder ten gevolge van laagfrequent geluid*, TNO, Soesterberg, 2010

[10] Pedersen, E., Persson Waye, K. Wind turbines—low level noise sources interfering with restoration?. *Environ. Res. Lett.* ***3*** *(2008) 015002 (5pp)*