Transmitted by the expert from the Netherlands

Informal document No. **GRB-41-8**
(41st GRB, 22-24 February 2005
agenda item 4.)

INFLUENCE OF LOW FREQUENCY NOISE ON HEALTH AND WELL-BEING

Martin van den Berg
Ministry of Environment
The Hague, Netherlands
Date: 11 February 2005

1. Introduction.

The lowest frequency of sound that we can hear is around 20 Hz, which normally corresponds to a wavelength of 15 meters. To generate sound with these frequencies, relatively large dimensions and energies are therefore required. This can be noted with large church organs: the lowest tones are produced by pipes so huge that a person can sometimes stand in it.
The increase in power ratings and dimensions of cars, trucks and other equipment makes low-frequency noise an increasing worry. Unfortunately the present rating methods for noise levels rely on the A-weighted levels, which severely underestimate the impact of the low-frequencies. In this paper the impact of low-frequency noise or the share of low-frequency in noises from various sources on human health and well being is investigated.

2. Definitions and perception

For the purpose of this paper the following distinction is made:
1. < 20 Hz: infrasound
2. 20-100 Hz: low-frequency sound

Vibrations of objects in contact with the body are not taking into consideration, but noise induced vibrations as visible or audible effect are.
The distinctions between infrasound, low-frequency sound and high frequency sound are to some extent arbitrary. The perception thresholds given in the literature are derived under circumstances where except the ear also other body perceptions could be used to indicate the presence of a sound. At frequencies below 10 Hz the internal organs definitely start to resonate, but between 10 and 100 Hz the presence of a low-frequency sound probably can be just as much felt as heard.
The maximum sensitivity for sounds is around 1000 Hz, and defines the reference for the dB scale. It should be noted that this is the 50% hearing threshold: 50% of the people have therefore a lower threshold. In the next table the perception thresholds for the lower frequency range for 90%, 50% and 10% of the population.

Frequency (Hz)	Perception threshold (in dB re 20 μP) exceeded by the population		
	90%	*50%*	*10%*
4	107	119	135
10	92	103	119
20	74	85	101
50	39	50	66
100	22	34	50

This means that a tone of 20 Hz at a level of 74 dB will be heard by 10% of the population, while at a level of 101 dB 90% will hear this. It should be noted that the loudness of low frequency sounds increases rapidly with the level.

3. A-weighting and low-frequency

The A-weighting is based on the loudness thresholds for low level sounds. In every day practice, frequencies below 30 Hz are neglected and the 31,5 Hz octaveband is reduced by 39.4 dB, and the 63 Hz band with 26.2 dB. This neglects the fact that the loudness corrections for low frequency sounds decrease sharply with level: at 70 dB (1000 Hz) the "A-weight"of the 31 Hz band should be 20 instead of 40 dB.
In a static situation (meaning: if the relative shares of frequencies remain more or less the same) this is not important. If however the relative share of low frequency increases and the resulting A-weighted sound level is valued with the same criteria, a serious error may result

4. Effects on health & wellbeing

Health and wellbeing effects of noise have been extensively described. Although research is still carried out into details of the dose-effect relationships, there is little discussion about the following effects and thresholds:

Table 1: health effects in relation to their scientific status and their respective threshold levels for exposure.

		Noise exposure threshold level		
	situation	noise index	Value in dB(A)	inside/outside
Enough scientific evidence				
- hearing impairment	work	L_{Aeq},8hr	75	inside
	sport	L_{Aeq},24hr	70	inside
- blood pressure	work	L_{Aeq},8hr	<85	inside
	home	L_{Aeq},6-22hr	70	outside
- ischaemic heart diseases	home	L_{Aeq},6-22hr	70	outside
- annoyance	home	L_{dn}	42	outside
- awakening	sleep	SEL	55	inside
- sleep stadia	sleep	SEL	35	inside
- self reported quality of sleep	sleep	L_{Aeq},night	40	outside
- performance at school	school	L_{Aeq},day	70	outside
Limited scientific evidence				
- weight at birth				
- immune system				
- psychiatric disorder				
Inadequate scientific evidence				
- congenital defects				
- immune system	sleep			

Source: Dutch Health Council , Noise and Health, september 1994

These data are all based on measured or calculated A-weighted levels, and so donot take low frequency separately into account. For some effects it is clear that a higher than average low frequency content influences the relation between the A-weighted level and the effect. Further studies indicate effects of low-frequency noise where this is the main source:

- complaints
- stress
- loss of concentration.
- Depression
- Insomnia
- Loss of cilia

Recently it was demonstrated (Litt 8,9)that in animal low frequency noise can lead to the loss of cilia in the cochlea as well as in the trachea, with potentially very serious health consequences. High level low frequency sounds could be used as an acoustich fence, showing again the high biological potential of these sounds.
For annoyance however the influence of lowfrequency content is well studied (Litt 1, 2 and 3). Most of this coming from studies of the effects of heavy artillerie. The main finding is that the relation between rating level and effect improves substantially if the difference between A-weighted and C-weighted level is taken into account. Preliminary results for road traffic indicate that this is also valid there. The current best estimate for a low-frequency adjustment is based on the difference between C-weighted and A-weighted levels, in the general form:

$$L_{LF,adj} = L_A + \alpha*(L_C - L_A)*(L_A - \beta)$$

Where L_A = the A-weighted level, L_C = C-weighted level and α and β are empiric correction factors. The best estimate for $\alpha=0.015$ and $\beta= 47$.

5. Prevalence

A large scale study (Litt 7) shows that for many sources large differences between A-weighted and C-weighted levels do occur in practice. The following table shows typical results.

Difference between A-weighted SEL and C-weighted SEL for different sources in dB		
Source	Average	Maximum
Railtraffic	5.3	15
Roadtraffic	7.1	15
Aircraft	9.1	13
Industry	13.2	24
Ships	13.8	21

This is based on outside measurements. As houses block higher frequencies much beter than lower, the differences inside may be 5-15 dB higher.
As a result a relative large proportion in the population states to experience sensations that may be attributed to low frequency or even infrasound. The 1998 Dutch survey (Litt 8) indicates that 15% of the population is possibly involved, 3% definitely. In this figure are not counted the 3% that state to be highly annoyed by vibrations from aircraft; from straightforward reasoning this must be induced by low frequency air borne sounds.

6. Limits

In view of the above health authorities in often set limits or guidelines to the levels of low frequency noise. A very good example are the “Danish guidelines on environmental low frequency noise, infrasound and vibration”, latest update 2002(Litt 5). Like other guidelines, this one takes the view that in order to avoid effects, low frequency sounds should be below the hearing threshold.

7. Type approval methods

Current type approval methods are based on A-weighted measurements, thereby setting no limit to the share of low frequency sounds in the emission. This could be remdiated by applying the correction factor described in paragraph 4.

8. Conclusion

Low frequency sound can have far reaching biological consequences which scientists are just beginning to understand. In view of this the precautionary principle demands that at least further increase of low frequency should be limited. Relatively simple methods are available.

9. References

1. Vos, J (2001). On the annoyance caused by impulse sounds produced by small, medium-large, and large firearms. *Journal of the Acoustical Society of America, 109 (1),* 244-253.
2. Vos, J (2003). A- and C-weighted sound levels as predictors of the annoyance caused by shooting sounds. JASA, 113(1), 336-347
3. Vos, J, (2030). Annoyance caused by magnetic levitation train,TNO TM-03-C001, Soesterberg
4. NSG (1999) Richtlijn Laagfrequent geluid, Delft
5. Miljostyrelsen, 2002, Danish guidelines on environmental low frequency noise
6. R.G. de Jong J.H.M. Steenbekkers H. Vos, (2000) Hinder en andere zelf-gerapporteerde effecten van milieuverontreiniging in Nederland. Inventarisatie verstoringen 1998; TNO, *PG/VGZ/2000.012* Leiden
7. Ploeg, F vd, (2003). 1ste inventarisatie correctiefactor laagfrequent geluid, Peutz&ass, Mook
8. M. Alves-Pereira, N. A. A. Castelo Branco,(2003) Ciliated cells, cochlear cilia & low frequency noise, ICBEN 2003, Rotterdam
9. Sharp (2003) Intense LF noise effects on humans , ICBEN 2003, Rotterdam