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NOISE-INDUCED SLEEP DISTURBANCE

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INTRODUCTION

In recent years there have been several reviews and studies concerned with noise-induced sleep disturbance (see ASHA, 1980), although not many have had the aim of determining acceptable night-time noise limits in residential areas. The necessity of determining such limits arises from the need to reduce to a minimum noise-induced sleep disturbance, since this is sometimes judged to be a deleterious consequence of living in a noisy environment as it may adversely affect health and general well-being.

The outdoor noise level limits recommended by a number of international bodies as being appropriate for undisturbed sleep show a surprising degree of uniformity, no doubt because much of the same scientific data was reviewed in each case.

The World Health Organisation (WHO, 1980) recommends that a level of less than 35 dB(A) should be maintained in order to preserve the restorative process of sleep. The Organisation for Economic Cooperation and Development (OECD, 1978) states that criteria provisionally recommended in some member countries are 35 dB(A) for the time taken to get to sleep, 45 dB(A) for light sleep (stages 1 and 2) and 50 dB(A) for deep sleep (stages 3 and 4) interruption. The Commission for European Communities (CEC, 1975) believe that the equivalent continuous sound level which would not affect sleep at all lies somewhere between 30 and 35 L_{Aeq}, with noise peaks not exceeding about 45 dB(A).

The outdoor noise level values associated with these limits may be estimated as being some 5-20 dB(A) higher, depending upon the construction of the dwelling and its window configuration. A reasonable approximation would seem to be 10-15 dB. It might therefore be concluded that the acceptable outdoor limit for undisturbed sleep in the presence of noise over the period 2200-0700 hours is an L_{Aeq} of 45 dB, with noise peaks not exceeding about 60 dB.

There is disquiet in some circles that these limits are not only too conservative but are too costly to implement as well. It is felt that the preservation of totally undisturbed sleep is unreasonable and that planning criteria should make allowance for some inevitable interference and minimal awakening.

Much of the information relating to noise-induced sleep disturbance is related to transportation noise, and whilst it is evident that different noise sources can evoke different human reactions, the prediction of these responses is also dependent upon mediating variables. These include age, sex and state of health; the way in which these factors interact with a person's prior experience of and association with the noise; the location of the bedroom within the house; the times of night during which the noise occurs, and the influence of other noises heard in combination. Whilst the quantification of these variables is virtually impossible, there is nevertheless some evidence to suggest that about 20% of the population have sleeping difficulties which appear to be totally unrelated to noise.

CRITERION BASELINE

Data relating to noise-induced sleep disturbance may be obtained from three main sources: social surveys, field studies and laboratory studies. Each of these approaches has advantages and disadvantages which are interesting to bear in mind when drawing overall conclusions. For example the results of laboratory studies seem to indicate that sleep disturbance effects occur at levels up to 5 dB less than those reported in social survey and field studies.

In a recent review Rice and Morgan (1982) found that remarkably few social surveys have been carried out to specially investigate noise-induced sleep disturbance. Those worthy of specific mention are the studies of traffic noise by Langdon and Buller (1977) and aircraft noise by DORA (1980). A principal finding of both was that about 20% (Langdon and Buller) and 25% (DORA) of the sampled populations reported sleep disturbance which could be attributed to causes other than noise.

These findings would seem to indicate that source specific noise-induced sleep disturbance cannot be expected to become a problem in its own right until population responses of the order of 25% are reported. It was on the basis of this overall generalisation that the available published literature was reviewed and formulated into a criterion for consideration for use in planning for noise reduction.

FINDINGS

1. Considerable disparity is evident from the reviewed data on 'awakening thresholds' to sound levels of different character and intensity. In fact it is unlikely that a fixed threshold will be found below which 'no awakenings' occur, rather a range of sound levels exists within which sleep disturbance (awakenings in particular) will be minimal. This range tends to fall in the L_{Aeq} region 40-60 dB(A) when measured indoors for a variety of noise sources, with peak levels up to 30 dB higher. The data also precludes the formulation of a dose-response type relationship which relates sleep disturbance *per se* to noise exposure for all noise sources.

2. It is quite clear that several mediating variables play significant rôles in the formulation of a definitive criterion for the prediction of sleep disturbance due to noise, and the present state of knowledge is such that the following factors are important but cannot always be quantitatively accounted for:-

Sleep norms - about 20% of the population have sleeping difficulties which are unrelated to noise.

Age, sex, attitudes, and health - these factors often over-ride the impact of noise-induced sleep disturbance.

Background noise - the extent to which sleep disturbance is attributed to noise is influenced not only by attitudinal factors, but also by prevailing background noise levels. The detection of noise peaks emerging from background noise during sleep has also received insufficient attention. The detectability/emergence models of sleep disturbance are worthy of further research effort.

Habituation - can occur over periods varying from days to several months following the onset of noise.

Bedroom location - the position of the bedroom with respect to the noise sources, together with open or closed window situations influence responses.

Time of night - the most vulnerable times are those during which people are trying to get to sleep (i.e., 2200-2400 hours) and the latter part of the night when lighter sleep stages naturally predominate.

Noise sources - different noise sources do not evoke the same sleep disturbance effects.

3. It is considered both unrealistic and often impracticable to set as acceptable night-time noise limits in community areas, noise levels which cannot be reasonably complied with. Such a criterion is the often proposed (WHO/EEC/OECD) indoor L_{Aeq} of 30-35 dB with peak levels up to 10 dB higher. Whilst this may completely preserve the restorative process of sleep, it does not allow much if any account to be taken of the mediating variables.

4. The accompanying table synthesises the data which have been reviewed. It should be noted that the values refer to 25% of the population who are likely to suffer sleep disturbance from all causes, and is thought to represent those outdoor levels at which source-specific effects may be identified.

Noise Source	L_{Aeq}	Peak dB(A)
Traffic	55	75
Steady noises	55	80
Aircraft	60	85
Trains	60	85

5. For planning purposes the criterion should be interpreted in the following way. Source-specific noise disturbance of sleep may be expected to become significant once the outdoor night-time (2200-0700 hour) L_{Aeq} exceeds 55 dB providing the peak levels do not exceed about 75-80 dB. Higher L_{Aeq} values up to 60 dB may be allowed providing the peak levels do not exceed 85 dB(A), and the number of such events is less than about 20 per night. In this latter context, special account also needs to be taken of the 2200-2400 going-to-sleep period, when particularly noisy events should be avoided.

6. The concept of the independent effects model has been utilised in which daytime and evenings annoyance to noise must be separately evaluated using an energy summation model (i.e., a day-evening weighted L_{Aeq}), the above proposed night-time criterion being used to establish the onset of noise-specific sleep disturbance. Such an independent effects model might separately include day-evening and night-time terms of the form

$$L_{de} = 10 \log\{10^{(L_d-5)/10} + 10^{L_e/10}\} \text{ and } \quad L_n = \text{fn}(L_n, L_{Amax}, N)$$

L_d = 0700–1800, L_e = 1800–2200, L_n = 2200–0700 h L_{Aeq}

L_{Amax} is the average peak noise level of N events.

CONCLUSIONS

Numerous laboratory, field and social survey studies have produced information relating to noise-induced sleep disturbance. Collation and comparison of this data reveals certain trends which may be formulated into a planning criterion.

Much of the information relates to transportation noise, in particular that produced by aircraft and traffic. As well as different sources producing different responses, other variables which play important rôles are age, sex, attitude, general health, habituation, bedroom location, time of occurrence during the night, and the influence of other noises when heard in combination.

The most important single factor, however, is that about 20% of the population have sleeping difficulties which appear to be totally unrelated to noise, people often wrongly reporting that their sleep disturbance is noise related. Therefore, in order to be certain that source-specific noise-induced sleep disturbance occurs, a general reported population response of 25% is required. This finding forms the basis of the criterion.

It is proposed that sleep disturbance will start to become significant once the outdoor night-time (2200–0700 h) L_{Aeq} exceeds 55–60 dB, providing maximum levels do not exceed 75 dB(A). Levels up to 85 dB(A) may be allowed providing the number of such events does not exceed 20 per night.

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