

AIRCRAFT NOISE AND SLEEP DISTURBANCE: A REVIEW OF FIELD STUDIES

David S. Michaud, Ph.D

Health Canada, Consumer and Clinical Radiation Protection Bureau, Product Safety Programme, Acoustics Division,
775 Brookfield Road, Ottawa, ON K1A 1C1 dmichaud@hc-sc.gc.ca

1. INTRODUCTION

According to the World Health Organization (WHO) (1), health should be regarded as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Adequate sleep is fundamental to physical and mental restoration. Thus, aircraft noise-induced sleep disturbance (AN-ISD) should be viewed as a potential health hazard, according to the WHO's definition of health.

AN-ISD includes circumstances where aircraft noise (i) interfered with the ability to fall asleep, (ii) curtailed sleep duration, (iii) decreased perceived quality of sleep, (iv) caused awakening(s) during sleep or (v) increased bodily movements during sleep (i.e. motility).

2. METHODS

Field research related to AN-ISD published in English since 1992 was identified using electronic databases, internet searches and conference proceedings. Electroencephalography, which measures electrical activity of the brain, is still considered to be the "gold standard" in sleep research; however it has some practical disadvantages that make the relative simplicity of monitoring motility and objective measures of awakenings a desirable alternative to sleep researchers. As such, most of the studies in this review assess sleep disturbance by monitoring motility and awakenings. Since available dose-response curves are based on behaviourally confirmed awakenings, the present paper focuses primarily on these results. Behaviourally confirmed awakenings are typically confirmed when the subject presses a button when awakened.

3. RESULTS

3.1 Heathrow, Gatwick, Stanstead and Manchester Airports study, United Kingdom

In 1992 a field study was conducted to assess AN-ISD in the UK (3). The focus was on the impact that aircraft noise had on awakenings and motility in 400 subjects between 20-70 years of age over 5,742 subject

nights. Outdoor noise measurements were monitored to provide aircraft noise event (ANE) data. At outdoor maximum sound levels (L_{max}) above 80 dBA, the probability of an awakening was 1 in 75, but below this level ANEs were unlikely to cause an awakening. Aircraft noise was deemed to minimally contribute to awakenings on average, but noise sensitive individuals were up to two times more likely to be awakened by an ANE than individuals classified as the least sensitive to noise. As reported in the US studies below, sleep in general became more disturbed as the night progressed, but this was not a result of ANEs *per se*.

3.2 U.S.A field studies on aircraft noise and sleep disturbance

Fidell et al. (4) assessed the effects of aircraft noise on behaviourally confirmed awakenings over approximately one month in 27 subjects living near a military airfield and 35 subjects living near the Los Angeles International Airport (LAX). An additional 23 subjects living without significant amounts of aircraft noise (mostly traffic) served as controls. Indoor Leq levels were recorded every 2-sec within the bedrooms of all participants and noise events (presumed to be aircraft) were logged every 0.5 sec. Across all 3 study locations, spontaneous awakenings were much more common than those resulting from an aircraft noise event (2.07 vs. 0.24/night, respectively). The mean indoor sound exposure level (SEL) of a noise event that awakened subjects was 80.6 dB, while events with an SEL of 74.1 dB failed to awaken participants. An increase of 10 dB SEL for indoor noise event levels was associated with a 1.6% increase in the percentage of people awakening. Awakenings were not affected when aircraft activity at the military airfield was reduced over weekends (from 53.5 to 47.7 Leq). As reported in the UK study, the probability of awakening was dependent upon the time since going to bed. In this study, for each 15 min since going to bed, the probability of awakening to a noise event increased by a factor of 1.06. Cumulative noise exposure over the entire night was unable to predict sleep disturbance.

Fidell et al. (1995) (5) assessed behaviourally confirmed awakenings and motility in 77 subjects over 2,717 subject nights around the Stapleton International Airport (DEN),

which was about to close and the Denver International Airport (DIA), which was scheduled to open. As a function of indoor noise events (presumably aircraft), the percentage of people awakening increased by 0.25% per 1 dB increase in indoor SEL (average threshold ~ 69 dBA). Ambient sound levels (Leq) within the bedrooms were inversely related to noise event associated sleep disturbance. Prior to opening DIA, there was an average of 1.71 behavioural awakenings per night that dropped to 1.13 per night after opening. Awakenings before and after the closing of DEN were not statistically different (1.8 vs. 1.64, respectively). The indoor SEL that caused motility ranged from 65-74dB and motility increased by 0.4-1.23% for each 1dB increase in SEL.

Using similar methodology, Fidell et al (2000) (6) measured indoor and outdoor sound levels in 12 homes (22 participants) around the DeKalb-Peachtree Airport (PDK) before, during and following the Atlanta Olympic Games. Average awakenings were higher before (1.8 per night), dropping slightly to 1.3 during and to 1.0 following the games. For each 10 dB increase in the indoor SEL there was an increase of 1.3% in the percentage of people awakened. At an outdoor SEL of 100dBA there was large variability in the prevalence of awakening (0 to 20%), which was less apparent at 60 dBA (0-2%).

3.3 Amsterdam Schiphol Airport (AMS), The Netherlands

The impact of aircraft noise from AMS on sleep disturbance has recently been reported in 418 subjects between 18-81 years of age (7). Aircraft noise was monitored within subject's bedrooms and at selected outdoor locations over an 11 day period. Behaviourally confirmed awakenings were statistically more likely to occur during an ANE compared to outside the event; but were not influenced by the indoor Lmax nor SEL of an ANE. The indoor Lmax of an ANE did predict motility. The threshold for the probability of motility was 32dBA indoor Lmax and increased as levels increased so that, at 68dBA, the probability of motility during aircraft noise was about 3 times greater than in the absence of aircraft noise. Subjects that were on average exposed to minimal ANEs at night, that yield a lower night time Leq, were more likely to respond to an ANE with an increase in motility compared to subjects exposed to higher night time Leq levels from aircraft noise. However, mean motility (averaged over 11 days) increased with higher indoor equivalent noise levels from aircraft.

4. DISCUSSION

These studies show that aircraft noise can be a significant source of sleep disturbance for a small percentage of a population exposed to nighttime aircraft

noise. This may be a significant number of individuals, even though the majority of exposed people does not show measurable signs of disturbance. Thus, future research might best protect susceptible exposed individuals by elucidating the factors that contribute to the range in individual AN-ISD.

The studies reviewed here also suggest that, ideally, the AN-ISD element of environmental assessment guidelines should incorporate indoor sound levels based on single aircraft noise events. Indeed, a recent meta-analysis of field data produced a dose-response curve for aircraft noise and awakenings based on the indoor SEL:

$$\% \text{ Awakenings} = 0.58 + (4.30 \cdot 10^{-8}) \text{ SEL}^{4.11} \quad (8)$$

Environmental assessment will undoubtedly improve if researchers are able to establish the cumulative health effects of AN-ISD and how to best assess sleep disturbance (motility, awakenings, stage change, complaint behaviour, etc.).

It is not known if the general conclusions from the studies reviewed here are in agreement with trends in complaint behaviour from people residing near airports. Guidance for health impact assessment of aircraft noise would be improved if research could identify the relationship between logged complaints and measures of sleep disturbance presented by noise researchers in peer review journals.

5. REFERENCES

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