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ВСЕМИРНАЯ ОРГАНИЗАЦИЯ ЗДРАВООХРАНЕНИЯ
ЕВРОПЕЙСКОЕ РЕГИОНАЛЬНОЕ БЮРО

EUROPEAN CENTRE FOR ENVIRONMENT AND HEALTH
BONN OFFICE

NIGHT NOISE GUIDELINES (NNGL) FOR EUROPE

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Between the European Commission, DG Sanco
and the World Health Organization, Regional Office for Europe

Final implementation report

Notice The following are excerpts from the study that relate to preventing adverse health effects from nighttime noise and sleep disturbance. In some cases sections have been rearranged for this summary. [1]

"Introduction

"Policies and legislations aiming at night noise control are often based on sleep disturbance in European countries. However, the impacts of noise-induced sleep disturbance on health, either short-term or long-term, have not been investigated comprehensively to support policy-makers. From June 2003 until December 2006, WHO Regional Office for Europe European Centre for Environment and Health (Bonn office) implemented the Night Noise Guideline (NNGL) project co-sponsored by the European Commission.

"The goal of the NNGL project was to provide expertise and scientific advice to the European Commission and its Member States in developing future legislations in the area of night noise exposure control and surveillance. The key objectives of the project was to reach a consensus of experts and stakeholders on the following subjects: (a) guideline values for night noise to protect the public from

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adverse health effects, (b) an agreement on the night penalty factor to be allocated to night time noise in the calculation of L_{den}.[2]

"10 Relation to the 2000 *WHO Guidelines for Community Noise*

"The *WHO Guidelines for Community Noise*, published in 2000, also address night noise. As they are based on studies carried out up to 1995 (and a few meta-analyses some years after), important new studies have become available since then, together with new insights into normal and disturbed sleep.

"The currently recommended guideline values of Lnight,outside = 30 dB, 40dB, 55 dB are not directly comparable with the 2000 guideline value of LAmax,inside = 45 dB(A) because the sound level units are different. However, it is clear that new information since 2000 has made more precise assessment of the risk from night noise. The thresholds for a number of effects are now known, and this is much lower than an LAmax,inside of 45 dB.

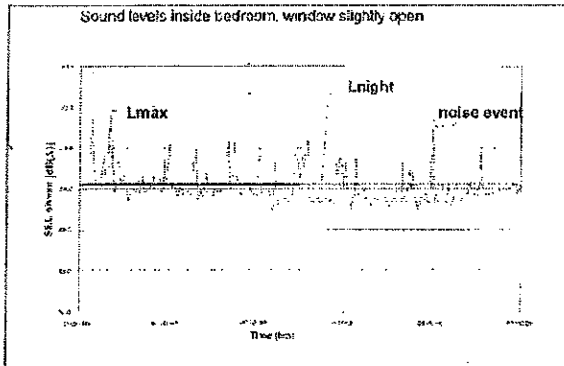

Figure 6. Relation between L_{night}, L_{Amax} and SEL. This is a sound recording in a bedroom for one night. The top of the peaks are the L_{Amax}-levels, the total energy is the L_{night} (thick horizontal line). The sound energy in one event is the SEL (not represented). In reality the L_{night} is the average over all nights in one year.

"One important recommendation still stands: there are good reasons for people to sleep with their windows open, and to prevent sleep disturbances one should consider the equivalent sound pressure level and the number of sound events. The present guidelines allow relevant authorities and stakeholders to do this. Viewed in this way, the present guidelines may be considered as an extension to, as well as an update of, the 2000 WHO *Guidelines for Community Noise*. That also means that the recommendations contained in the sections on noise management and control of 2000 document can be applied to the guideline values of this document.

"5 Noise, sleep and health

"There is plenty of evidence that sleep is a biological necessity, and disturbed sleep is associated with a number of health problems. Studies of sleep disturbance in children and in shift workers clearly show the adverse effects.

> *"**Sufficient evidence:** A causal relation has been established between exposure to night noise and a health effect. In studies where coincidence, bias and distortion could reasonably be excluded, the relation could be observed. The biological plausibility of the noise leading to the health effect is also well established.*
> *"**Limited evidence:** A relation between the noise and the health effect has not been observed directly, but there is available evidence of good quality supporting the causal association. Indirect evidence is often abundant, linking noise exposure to an intermediate effect of physiological changes which lead to the adverse health effects."*

"Noise disturbs sleep by a number of direct and indirect pathways. Even at very low levels physiological reactions (increase in heart rate, body movements and arousals) can be reliably measured. Also, it was shown that awakening reactions are relatively rare, occurring at a much higher level than the physiological reactions.

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[2] "The methodology of developing night noise guidelines was based on the WHO publication EUR/00/5020369 "Evaluation and use of epidemiological evidence for environmental risk assessment" that can be accessible at http://www.euro.who.int/document/e68940.pdf.

"The working group agreed that there is sufficient evidence that night noise is related to self-reported sleep disturbance, use of pharmaceuticals, self-reported health problems and insomnia like symptoms. These effects can lead to a considerable burden of disease in the population. For other effects (hypertension, myocardial infarctions, depression and others), limited evidence was found: although the studies were few or not conclusive, a biologically plausible pathway could be constructed from the evidence.

"An example of a health effect with limited evidence is myocardial infarctions. Although evidence for increased risk of myocardial infarctions related to Lday is sufficient according to an updated meta-analysis, the evidence in relation to Lnight,outside was considered limited. This is because Lnight,outside is a relatively new exposure indicator, and few field studies have focused on night noise when considering cardiovascular outcomes. Nevertheless, there is evidence from animal and human studies supporting a hypothesis that night noise exposure might be more strongly associated with cardiovascular effects than daytime exposure, highlighting the need for future epidemiological studies on this topic.

"The review of available evidence leads to the following conclusions.

- Sleep is a biological necessity, and disturbed sleep is associated with a number of adverse impacts on health.
- There is sufficient evidence for biological effects of noise during sleep: increase in heart rate, arousals, sleep stage changes, hormone level changes and awakening.
- There is sufficient evidence that night noise exposure causes self-reported sleep disturbance, increase in medicine use, increase in body movements and (environmental) insomnia.
- While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia) it also leads to further consequences for health and well-being.
- There is limited evidence that disturbed sleep causes fatigue, accidents and reduced performance.
- There is limited evidence that noise at night causes clinical conditions such as cardiovascular illness, depression and other mental illness. It should be stressed that a plausible biological model is available with sufficient evidence for the elements of the causal chain.

"6 Vulnerable groups

"Children have a higher awakening threshold than adults and therefore are often seen to be less sensitive to night noise. For other effects, however, children seem to be equally or more reactive than adults. As children also spend more time in bed they are exposed more and to higher noise levels. For these reasons children are considered a risk group.

"Since with age the sleep structure becomes more fragmented, elderly people are more vulnerable to disturbance. This also happens in pregnant women and people with ill health, so they too are a group at risk.

"Finally, shift workers are at risk because their sleep structure is under stress due to the adaptations of their circadian rhythm.

"7 Thresholds for observed effects

The (no) observed adverse effect level (NOAEL) is a concept from toxicology, and is defined as the greatest concentration which causes no detectable adverse alteration of morphology, functional capacity, growth, development or lifespan of the target organism. For the topic of night noise (where the adversity of effects is not always clear) this concept is less useful. Instead, the observed effect thresholds are provided: the level above which an effect starts to occur or shows itself to be dependent on the exposure level. It can also be a serious pathological effect, such as myocardial infarctions, or a changed physiological effect, such as increased body movement.

Threshold levels of noise exposure are important milestones in the process of evaluating the health consequences of environmental exposure. The threshold levels also delimit the study area, which may

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lead to a better insight into overall consequences. In Table 1, all effects are summarized for which sufficient or *limited evidence* exists. For the effects with *sufficient evidence* the threshold levels are usually well known, and for some the dose-effect relations over a range of exposures could also be established.

	Effect	Indicator	Threshold, dB
Biological effects	Change in cardiovascular activity	*	*
	EEG awakening	LAmax,inside	35
	Motility, onset of motility	LAmax,inside	32
	Changes in duration of various stages of sleep, in sleep structure and fragmentation of sleep	LAmax,inside	35
Sleep quality	Waking up in the night and/or too early in the morning	LAmax,inside	42
	Prolongation of the sleep inception period, difficulty getting to sleep	*	*
	Sleep fragmentation, reduced sleeping time	*	*
	Increased average motility when sleeping	Lnight,outside	42
Well-being	Self-reported sleep disturbance	Lnight,outside	42
	Use of somnifacient drugs and sedatives	Lnight,outside	40
Medical conditions	Environmental insomnia[1]	Lnight,outside	42
* Although the effect has been shown to occur or a plausible biological pathway could be constructed, indicators or threshold levels could not be determined.			

Table 1. Summary of effects and threshold levels for effects where **sufficient** evidence is available.[3]

9 Recommendations for health protection

Sleep is an essential part of human functioning and is recognized as a fundamental right under the European Convention on Human Rights.2 Based on the evidence of the health effects of night noise, an overall summary of the relation between night noise levels and health effects, and stepwise guideline values are presented as shown in Table 3 and 4, respectively.

Table 3. Summary of the relation between night noise and health effects in the population Especially in the range Lnight,outside from 30 to 55 dB, a closer look may be needed into the precise impact as this may depend much on the exact circumstances. Above 55 dB the cardiovascular effects become the dominant effect, which is thought to be less dependent on the nature of the noise.

3 Please note that "environmental insomnia" is the result of diagnosis by a medical professional whilst "self-reported sleep disturbance" is essentially the same, but reported in the context of a social survey. Number of questions and exact wording may differ.

From Table 1, it is clear that a number of instantaneous effects are related to threshold levels expressed in L_{Amax}. The health relevance of these effects cannot be easily established. It can be safely assumed, however, that an increase in the number of such effects over the base line may constitute an subclinical adverse health effect.

For the primary prevention of subclinical adverse health effects in the population related to night noise, it is recommended that the population should not be exposed to night noise levels greater than 30 dB of Lnight,outside during the night when most people are in bed. Therefore, Lnight,outside 30 dB is the ultimate target of Night Noise Guideline (NNGL) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise.

Table 3. Summary of the relation between night noise and health effects in the population

$L_{night,outside}$ **up to 30 dB**	Although individual sensitivities and circumstances differ, it appears that up to this level no substantial biological effects are observed.
$L_{night,outside}$ **of 30 to 40 dB**	A number of effects are observed to increase: body movements, awakening, self-reported sleep disturbance, arousals. With the intensity of the effect depending on the nature of the source and on the number of events, even in the worst cases the effects seem modest. It cannot be ruled out that vulnerable groups (for example children, the chronically ill and the elderly) are affected to some degree.
$L_{night,outside}$ **of 40 to 55 dB**	There is a sharp increase in adverse health effects, and many of the exposed population are now affected and have to adapt their lives to cope with the noise. Vulnerable groups are now severely affected.
$L_{night,outside}$ **of above 55 dB**	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a high percentage of the population is highly annoyed and there is some limited evidence that the cardiovascular system is coming under stress.

End of WHO 2007 Guideline Excerpts

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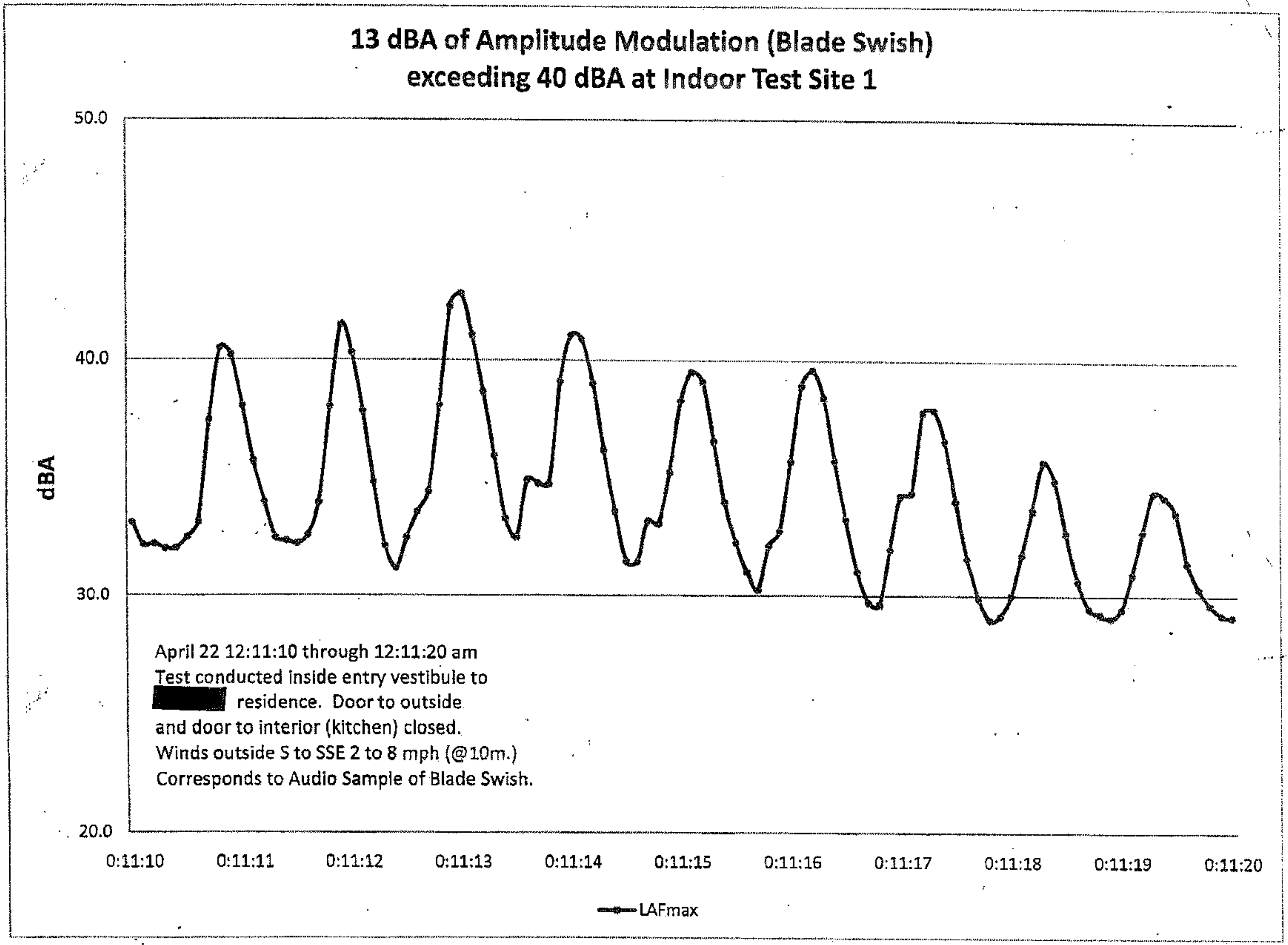
13 dBA of Amplitude Modulation (Blade Swish)
exceeding 40 dBA at Indoor Test Site 1
50.0
40.0
30.0
20.0
dBA
April 22 12:11:10 through 12:11:20 am
Test conducted inside entry vestibule to
[redacted] residence. Door to outside
and door to interior (kitchen) closed.
Winds outside S to SSE 2 to 8 mph (@10m.)
Corresponds to Audio Sample of Blade Swish.
0:11:10
0:11:11
0:11:12
0:11:13
0:11:14
0:11:15
0:11:16
0:11:17
0:11:18
0:11:19
0:11:20
LAFmax

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GUIDELINES

FOR

COMMUNITY NOISE

Edited by

Birgitta Berglund
Thomas Lindvall
Dietrich H Schwela

This WHO document on the *Guidelines for Community Noise* is the outcome of the WHO- expert task force meeting held in London, United Kingdom, in April 1999. It bases on the document entitled "Community Noise" that was prepared for the World Health Organization and published in 1995 by the Stockholm University and Karolinska Institute.

World Health Organization, Geneva
Cluster of Sustainable Development and Healthy Environment (SDE)
Department of the Protection of the Human Environment (PHE)
Occupational and Environmental Health (OEH)

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(Miedema & Vos 1998) and that obtained in a survey along the North-South transportation route through the Austrian Alps (Lercher 1998b). The differences may be explained in terms of the influence of topography and meteorological factors on acoustical measures, as well as the low background noise level on the mountain slopes.

Stronger reactions have been observed when noise is accompanied by vibrations and contains low frequency components (Paulsen & Kastka 1995; Öhrström 1997; for review see Berglund et al. 1996), or when the noise contains impulses, such as shooting noise (Buchta 1996; Vos 1996; Smoorenburg 1998). Stronger, but temporary, reactions also occur when noise exposure is increased over time, in comparison to situations with constant noise exposure (e.g. HCN 1997; Klæboe et al. 1998). Conversely, for road traffic noise, the introduction of noise protection barriers in residential areas resulted in smaller reductions in annoyance than expected for a stationary situation (Kastka et al. 1995).

To obtain an indicator for annoyance, other methods of combining parameters of noise exposure have been extensively tested, in addition to metrics such as LAeq,24h and L_{dn}. When used for a set of community noises, these indicators correlate well both among themselves and with LAeq,24h or L_{dn} values (e.g. HCN 1997). Although LAeq,24h and L_{dn} are in most cases acceptable approximations, there is a growing concern that all the component parameters of the noise should be individually assessed in noise exposure investigations, at least in the complex cases (Berglund & Lindvall 1995).

3.9. The Effects of Combined Noise Sources

Many acoustical environments consist of sounds from more than one source. For these environments, health effects are associated with the total noise exposure, rather than with the noise from a single source (WHO 1980b). When considering hearing impairment, for example, the total noise exposure can be expressed in terms of LAeq,24h for the combined sources. For other adverse health effects, however, such a simple model most likely will not apply. It is possible that some disturbances (e.g. speech interference, sleep disturbance) may more easily be attributed to specific noises. In cases where one noise source clearly dominates, the magnitude of an effect may be assessed by taking into account the dominant source only (HCN 1997). Furthermore, at a policy level, there may be little need to identify the adverse effect of each specific noise, unless the responsibility for these effects is to be shared among several polluters (*cf.* The Polluter Pays Principle in Chapter 5, UNCED 1992).

There is no consensus on a model for assessing the total annoyance due to a combination of environmental noise sources. This is partly due to a lack of research into the temporal patterns of combined noises. The current approach for assessing the effects of "mixed noise sources" is limited to data on "total annoyance" transformed to mathematical principles or rules of thumb (Ronnebaum et al. 1996; Vos 1992; Miedema 1996; Berglund & Nilsson 1997). Models to assess the total annoyance of combinations of environmental noises may not be applicable to those health effects for which the mechanisms of noise interaction are unknown, and for which different cumulative or synergistic effects cannot be ruled out. When noise is combined with different types of environmental agents, such as vibrations, ototoxic chemicals, or chemical odours, again there is insufficient knowledge to accurately assess the combined effects on health

(Berglund & Lindvall 1995; HCN 1994; Miedema 1996; Zeichart 1998; Passchier-Vermeer & Zeichart 1998). Therefore, caution should be exercised when trying to predict the adverse health effects of combined factors in residential populations.

The evidence on low-frequency noise is sufficiently strong to warrant immediate concern. Various industrial sources emit continuous low-frequency noise (compressors, pumps, diesel engines, fans, public works); and large aircraft, heavy-duty vehicles and railway traffic produce intermittent low-frequency noise. Low-frequency noise may also produce vibrations and rattles as secondary effects. Health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general (Berglund et al. 1996). Since A-weighting underestimates the sound pressure level of noise with low-frequency components, a better assessment of health effects would be to use C-weighting.

In residential populations heavy noise pollution will most certainly be associated with a combination of health effects. For example, cardiovascular disease, annoyance, speech interference at work and at home, and sleep disturbance. Therefore, it is important that the total adverse health load over 24 hours be considered and that the precautionary principle for sustainable development is applied in the management of health effects (see Chapter 5).

3.10. Vulnerable Groups

Protective standards are essentially derived from observations on the health effects of noise on "normal" or "average" populations. The participants of these investigations are selected from the general population and are usually adults. Sometimes, samples of participants are selected because of their easy availability. However, vulnerable groups of people are typically underrepresented. This group includes people with decreased personal abilities (old, ill, or depressed people); people with particular diseases or medical problems; people dealing with complex cognitive tasks, such as reading acquisition; people who are blind or who have hearing impairment; fetuses, babies and young children; and the elderly in general (Jansen 1987; AAP 1997). These people may be less able to cope with the impacts of noise exposure and be at greater risk for harmful effects.

Persons with impaired hearing are the most adversely affected with respect to speech intelligibility. Even slight hearing impairments in the high-frequency range may cause problems with speech perception in a noisy environment. From about 40 years of age, people typically demonstrate an impaired ability to understand difficult, spoken messages with low linguistic redundancy. Therefore, based on interference with speech perception, a majority of the population belongs to the vulnerable group.

Children have also been identified as vulnerable to noise exposure (see Agenda 21: UNCED 1992). The evidence on noise pollution and children's health is strong enough to warrant monitoring programmes at schools and preschools to protect children from the effects of noise. Follow up programmes to study the main health effects of noise on children, including effects on speech perception and reading acquisition, are also warranted in heavily noise polluted areas (Cohen et al. 1986; Evans et al. 1998).

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Report by

Dr Christopher HANNING

BSc, MB, BS, MRCS, LRCP, FRCA, MD

on

Sleep disturbance and wind turbine noise

on behalf of

Stop Swinford Wind Farm Action Group **(SSWFAG)**

June 2009

Contents

1. Introduction

1.1 The author

1.1.1. My name is Dr Christopher Hanning, Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, based at Leicester General Hospital, having retired in September 2007 as Consultant in Sleep Disorders Medicine. In 1969, I obtained a First class Honours BSc in Physiology and, in 1972, qualified in medicine, MB, BS, MRCP, LRCP from St Bartholomew's Hospital Medical School. After initial training in anaesthesia, I became a Fellow of the Royal College of Anaesthetists by examination in 1976 and was awarded a doctorate from the University of Leicester in 1996. I was appointed Senior Lecturer in Anaesthesia and Honorary Consultant Anaesthetist to Leicester General Hospital in 1981. In 1996, I was appointed Consultant Anaesthetist with a special interest in Sleep Medicine to Leicester General Hospital and Honorary Senior Lecturer to the University of Leicester.

1.1.2. My interest in sleep and its disorders began nearly 30 years ago and has grown ever since. I founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the country, until retirement. The University Hospitals of Leicester NHS Trust named the Sleep Laboratory after me as a mark of its esteem. I was a founder member and President of the British Sleep Society and its honorary secretary for four years and have written and lectured extensively on sleep and its disorders and continue an active research programme. My expertise in this field has been accepted by the civil, criminal and family courts. I chair the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sit on Advisory panels for several companies with interests in sleep medicine.

1.1.3. I live in Ashby Magna, Leicestershire which is subject to an application by Broadview Energy for a wind farm at Lower Spinney.

1.2. Brief from SSWFAG

1.2.1. My brief from SSWFAG was to review the potential consequences of wind turbine noise and, in particular, its effect on sleep and health and to make recommendations with regard to the proposed setback distances.

1.3. Scope of report.

1.3.1. This report centres on the effects of industrial wind turbine noise on sleep as this is the particular area of expertise of the author. Other areas of health concern related to low frequency noise emissions and vibro-acoustic disease will be left to others.

1.4. Source material

1.4.1. A full list of the publications reviewed and other source material is given in Section 7 and are cited in the text.

2. Background

2.1. Introduction

2.1.1. There can be no doubt that groups of industrial wind turbines ("wind farms") generate sufficient noise to disturb the sleep and impair the health of those living nearby. Section 5.1.1 of the draft New Zealand standard on wind farm noise, 2009, states: "Limits for wind farm noise are required to provide protection against sleep disturbance and maintain reasonable residential amenity." Reports from many different locations and different countries have a common set of symptoms and have been documented by Frey and Hadden (2007). New cases are documented regularly on the Internet. The symptoms include sleep disturbance, fatigue, headaches, dizziness, nausea, changes in mood and inability to concentrate and have been named "wind turbine syndrome" by Dr Nina Pierpont (2006), one of the principal researchers in this field. The experiences of the Davis (2008) and Rashleigh (2008) families from Lincolnshire whose homes were around 900m from wind turbines make salutary reading. The noise, sleep disturbance and ill health eventually drove them from their homes. Similar stories have been reported from around the world, in anecdotal form but in large numbers.

2.2. Sleep, sleep physiology and the effects of noise

2.2.1. Sleep is a universal phenomenon. Every living organism contains, within its DNA, genes for a body clock which regulates an activity-inactivity cycle. In mammals, including humans, this is expressed as one or more sleep periods per 24 hours. Sleep was previously thought to be a period of withdrawal from the world designed to allow the body to recuperate and repair itself. However, modern research has shown that sleep is primarily by the brain and for the brain. The major purpose of sleep seems to be the proper laying down and storage of memories, hence the need for adequate sleep in children to facilitate learning and the poor memory and cognitive function in adults with impaired sleep from whatever cause.

2.2.2. Inadequate sleep has been associated not just with fatigue, sleepiness and cognitive impairment but also with an increased risk of obesity, impaired glucose tolerance (risk of diabetes), high blood pressure, heart disease, cancer and depression. Sleepy people have an increased risk of road traffic accidents.

2.2.3 Humans have two types of sleep, slow wave (SWS) and rapid eye movement (REM). SWS is the deep sleep which occurs early in the night while REM or dreaming sleep occurs mostly in the second half of the night. Sleep is arranged in a succession of cycles, each lasting about 90 minutes. We commonly wake between cycles, particularly between the second and third, third and fourth and fourth and fifth cycles. Awakenings are not remembered if they are less than 30 seconds in duration. As we age, awakenings become more likely and longer so we start to remember them.

2.2.4. Noise interferes with sleep in several ways. Firstly, it may be sufficiently loud or annoying to prevent the onset of sleep or the return to sleep following an awakening. It is clear also that some types of noise are more annoying than others. Constant noise is less annoying than irregular noise which varies in frequency and loudness, for example, snoring, particularly if accompanied by the snorts of sleep apnoea (breath holding). The swishing or thumping noise associated with wind turbines seems to be particularly annoying as the frequency and loudness varies with changes in wind speed and local atmospheric conditions. While there is no doubt of the occurrence of these noises and their audibility over long distances, up to 3-4km in some reports, the actual cause has not yet been fully elucidated (Bowdler 2008). Despite recommendations by the Government's own Noise Working Group, UK research in this area has been stopped.

2.2.5. Secondly, noise experienced during sleep may arouse or awaken the sleeper. A sufficiently loud or prolonged noise will result in full awakening which may be long enough to recall. Short awakenings are not recalled as, during the transition from sleep to wakefulness, one of the last functions to recover is memory (strictly, the transfer of information from short term to long term memory). The reverse is true for the transition from wakefulness to sleep. Thus only awakenings of longer than 20-30 seconds are subsequently recalled. Research that relies on recalled awakenings alone may underestimate the effect.

2.2.6. Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred. It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep, because it is broken, is unrefreshing resulting in sleepiness, fatigue, headaches and poor memory and concentration (Martin 1997), many of the symptoms of "wind turbine syndrome". Arousals are associated not just with an increase in brain activity but also with physiological changes, an increase in heart rate and blood pressure, which are thought to be responsible for the increase in cardiovascular risk. Arousals occur naturally during sleep and increase with age (Boselli 1998) which may make the elderly more vulnerable to wind turbine noise. Arousals may be caused by sound events as low as 32 dBA and awakenings with events of 42dBA (Muzet and Miedema 2005), well within the measured noise levels of current "wind farms" and the levels permitted by ETSU-R-97 . Arousals in SWS may trigger a parasomnia (sleep walking, night terrors etc.). Pierpont (2009 and personal communication) notes that parasomnias developed in some of the children in her study group when exposed to turbine noise.

2.2.7. Arousals are caused by aircraft, railway and traffic noise. In one study of aircraft noise, arousals were four times more likely to result than awakenings (Basner 2008a&b). Freight trains are more likely to cause arousals than passenger trains, presumably because they are slower, generating more low frequency noise and taking longer to pass (Saremi 2008). The noise of wind turbines has been likened to a "passing train that never passes" which may explain why wind turbine noise is prone to cause sleep disruption.

2.2.8. It is often claimed that continual exposure to a noise results in habituation, i.e. one gets used to the noise. There is little research to confirm this assertion and a recent small study (Pirrera et al. 2009) looking at the effects of traffic noise on sleep efficiency suggests that it is not so.

2.2.9. Sleep disturbance and impairment of the ability to return to sleep is not trivial as almost all of us can testify. In the short term, the resulting deprivation of sleep results in daytime fatigue and sleepiness, poor concentration and memory function. Accident risks increase. In the longer term, sleep deprivation is linked to depression, weight gain, diabetes, high blood pressure and heart disease. There is a very large body of literature but please see Meerlo et al., 2008, Harding and Feldman, 2008 and Hart et al., 2008 for recent work on this subject. A more general review can found on Wikipedia: http://en.wikipedia.org/wiki/Sleep_deprivation

3. Wind turbine noise, sleep and health

3.1. Introduction

3.1.1. The evidence above demonstrates that it is entirely plausible that wind turbine noise has the potential to cause arousals, sleep fragmentation and sleep deprivation. As noted above, the draft New Zealand standard on wind farm noise (2009) acknowledges that sleep disturbance is the major consequence of wind turbine noise.

3.1.2 Unfortunately **all** government and industry sponsored research in this area has used **reported awakenings** from sleep as an index of the effects of turbine noise and dismisses the subjective symptoms. Because most of the sleep disturbance is not recalled, this approach seriously **underestimates** the effects of wind turbine noise on sleep.

3.2. Early research.

3.2.1. Surveys of residents living in the vicinity of industrial wind turbines show high levels of disturbance to sleep and annoyance. A 2005 survey of 200 residents living within 1km of a 6 turbine, 9MW installation in France showed that 27% found the noise disturbing at night (Butre 2005). A similar US survey in 2001 (Kabes 2001) of a "wind farm" in Kewaunee County, Wisconsin reported that 52% of those living within 400-800 metres found the noise to be a problem, 32% of those living within 800-1600 metres and 4% of those within 1600 and 3200 metres. 67% of those living within 250 to 400 metres and 35% of those within 400-800 metres reported being awoken by the sound in the previous year. The principal health problem reported by the 223 respondents was sleep loss. The landscape of Kewaunee County is described as "undulating to gently rolling", not dissimilar to South Leicestershire. All of these studies were of smaller turbines than proposed by Nuon. Pedersen and Waye (2004) reported that "16% (*n*=20, 95%CI: 11%–20%) of the 128 respondents living at sound exposure above 35.0 dBA stated that they were disturbed in their sleep by wind turbine noise."

3.2.2. Phipps and others (2007) surveyed 1100 New Zealand residents living up to 3.5 km from a wind farm, 604 responded. 75% of all respondents reported being able to hear the noise. Two separate developments have placed over 100 turbines with capacities from 600kW to 1.65MW in this hilly to mountainous area. It has been suggested that mountainous areas may allow low frequency noise to travel further which may explain the long distance over which the turbines were heard. Van den Berg (2004) found that residents up to 1900 m from a wind farm expressed annoyance with the noise, a finding replicated in his more recent study reported below. Dr Amanda Harry (2007), a UK GP, conducted surveys of a number of residents living near several different turbine sites and reported a similar constellation of symptoms from all sites. A study of 42 respondents showed that 81% felt their health had been affected, in 76% it was sufficiently severe to consult a doctor and 73% felt their life quality had been adversely impacted. This study is open to criticism for its design which invited symptom reporting and was not controlled. While the proportion of those affected may be questioned it nevertheless indicates strongly that some subjects are severely affected by wind turbine noise at distances thought by the industry to be safe.

3.3. Project WINDFARMperception

3.3.1. van den Berg and colleagues (2008) from the University of Groningen in the Netherlands have recently published a major questionnaire study of residents living within 2.5km from wind turbines, Project WINDFARMperception. A random selection of 725 residents were sent a similar questionnaire to that used by Pedersen in her studies in Sweden (2003, 2004, 2007 and 2008), questions on health, based on the validated General Heath Questionnaire (GHQ), were added. 37% replied which is good for a survey of this type but, nevertheless is a weakness. Questions on wind turbine noise were interspersed with questions on other environmental factors to avoid bias. The sound level at the residents' dwellings was calculated, knowing the turbine type and distance and the calculated ambient noise, derived from an environmental sound map of the Netherlands, according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime -that is: at high, but not maximum power. Noise exposure ranged between 24 and 54dBA. It is worth noting that the industry was approached for assistance in the research but refused. Complaints such as annoyance, waking from sleep, difficulty in returning to sleep and other health complaints were related to the calculated noise levels. Relevant conclusions include. *"Sound was the most annoying aspect of wind turbines"* and was more of an annoyance at night. Interrupted sleep and difficulty in returning to sleep increased with calculated noise level as did annoyance, both indoors and outdoors. Even at the lowest noise levels, 20% of respondents reported disturbed sleep at least one night per month. At a calculated noise level of 30-35dBA, 10% were rather or very annoyed at wind turbine sound, 20% at 35-40dBA and 25% at 40-43dBA (the permitted ETSU-R-97 night time level).

3.3.2. Project WINDFARMperception further found that *"Three out of four participants declare that swishing or lashing is a correct description of the sound from wind turbines. Perhaps the character of the sound is the cause of the relatively high degree of annoyance. Another possible cause is that the sound of modern wind turbines on average does not decrease at night, but rather becomes louder, whereas most other sources are less noisy at night. At the highest sound levels in this study (45 decibel or higher) there is also a higher prevalence of sleep disturbance."* The lack of a control group prevents this group from making firmer conclusions about turbine noise and sleep disturbance but it is clear that as ETSU-R-97 permits an exterior night time noise level of 43dB, relying on its calculations will guarantee disturbed sleep for those living nearby.

3.3.3. van den Berg concluded also that, contrary to industry belief, road noise does not adequately mask turbine noise and reduce annoyance and disturbance. In addition, they compared their results with studies by

Miedema on the annoyance from road, rail and air related noise. Wind turbine noise was several times more annoying than the other noise sources for equivalent noise levels (**Fig 1**). Similar data is given by Pedersen (2004) (**Fig 2**) – **see end of text** .

3.3.4 With regard to health it was concluded that: *"There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dBA) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or vice versa or whether both are related to another factor."* The conclusions regarding health are not justified from the data for the reasons given below and must be disregarded.

3.3.5. Project WINDFARMperception is currently the largest study in this field but the study is not without considerable flaws. The study may be criticised for using calculated noise levels and for not having a control group (residents not living near turbines). While several of the contributors have expertise in the investigation of health matters none has specific expertise in the physiology and pathophysiology of sleep. The purpose of the study, as its title suggested, was the public perception of wind turbines and their noise. Health questions were added but were of a very general nature. The small number of respondents suggests that any conclusions as to the apparent lack of an effect on health must be regarded as tentative.

3.3.6. The analysis of reported sleep interruption and wind turbine sound levels is flawed by the use of subjects exposed to calculated external sound levels of <30dBA (p53) as the "controls". It has been noted by several studies that calculated turbine noise is often less than measured noise and that levels as low as 30dBA can cause annoyance (Pedersen 2007). Examination of the odds ratio for different calculated sound levels (Table 7.42) shows that it increases progressively with increasing sound levels starting at 30-35dBA and becomes statistically significant for levels >45dBA. If, as is not impossible, the "control" group had its sleep disturbed by wind turbine noise then the actual effect would be considerably underestimated.

3.3.7. The major objection to the conclusions on health is that the study is grossly under-powered (insufficient subjects were studied for any degree of statistical confidence). Wind turbine syndrome, to the degree reported by Pierpont (2009), does not seem to be common even amongst those exposed to high noise levels. The study was designed to detect chronic disease with the GHQ, which is a fairly crude instrument. Assuming that wind turbine syndrome affects 1% of those exposed to calculated sound levels >45dBA and that 25% of the general population suffer from chronic disease (p47) then at least 30,000 subjects would need to be studied in each group (<45dBA v >30dBA) to be able to prove a difference with 95% certainty. Even if a prevalence of wind turbine syndrome of 5% of those exposed to >45dBA is assumed, then there must be at least 1250 subjects in each group. This study therefore can not conclude that wind turbines do not cause ill health of any degree, it can not even make conclusions about severe ill health.

3.4. Pierpont studies

3.4.1. Pierpont (2009 and personal communication) has recently completed a very detailed, peer-reviewed case-control study of 10 families around the world who have been so affected by wind turbine noise that they have had to leave their homes, nine of them permanently. The turbines ranged from 1.5 to 3MW capacity at distances between 305 to 1500m. The group comprised 21 adults, 7 teenagers and 10 children of whom 23 were interviewed. While this is a highly selected group, the ability to examine symptoms before, during and after exposure to turbine noise gives it a strength rarely found in similar case-control studies. The subjects described the symptoms of wind turbine syndrome outlined above and confirmed that they were not present before the turbines started operation and resolved once exposure ceased.

There was a clear relationship between the symptoms, even in children, and the noise exposure. She reports also that all adult subjects reported *"feeling jittery inside"* or *"internal quivering"*, often accompanied by anxiety, fearfulness, sleep disturbance and irritability. Pierpont offers compelling evidence that these symptoms are related to low frequency sound and suggests very plausible physiological mechanisms to explain the link between turbine exposure and the symptoms.

3.4.2. Of particular concern were the observed effects on children, include toddlers and school and college aged children. Changes in sleep pattern, behaviour and academic performance were noted. 7 of 10 children had a decline in their school performance while exposed to wind turbine noise which recovered after exposure ceased. In total, 20 of 34 study subjects reported problems with concentration or memory.

3.4.3. Pierpont's study mostly addresses the mechanism for the health problems associated with exposure to wind turbine noise rather than the likelihood of an individual developing symptoms. Nevertheless, it convincingly shows that **wind turbine noise does cause the symptoms of wind turbine syndrome**, including sleep disturbance. She concludes by calling for further research, particularly in children, and a 2km setback distance.

3.4.4. A recent paper (Todd et al, 2008) has shown that the vestibular system in the human ear, the part concerned with detection of movement and balance, is exquisitely sensitive to vibration at frequencies of around 100Hz. While this must be regarded as preliminary data, it does offer further evidence in support of Dr Pierpont's findings and theories.

3.5. DTI report

3.5.1. Nuon is likely to refer to a DTI report by the Hayes McKenzie Partnership published in 2006 which investigated low frequency noise at three UK wind farms. Hayes McKenzie have a long term relationship with the wind turbine industry, are noise engineers with no medical or physiological expertise so their suitability to undertake the work must be questioned. They took sound measurements at three of five sites where complaints had been recorded over periods from 1-2 months. Communication with residents other than those who complained was minimal. However, they did confirm that *"some wind farms clearly result in modulation at night which is greater than that assumed with the ETSU-R-97 guidelines"*. Measured *"internal noise levels were insufficient to wake up residents at these three sites. However, once awoken, this noise can result in difficulties in returning to sleep."* The lack of physiological expertise in the investigators in not recognising that noise can disturb sleep without actual recalled awakening is a major methodological flaw rendering the conclusions unreliable, as is the short recording period. It is well recognised also that not every resident affected by a nuisance such as noise will actually register a complaint. Many will not be sufficiently literate or confident so to do and others may wish to avoid drawing attention to the problem to protect property prices. They may assume also that protest is futile, which seems to be the experience of many with wind turbine noise. Recorded complaints are thus the tip of the iceberg.

3.5.2. It will be claimed also that only 5 of 126 wind energy developments at the time of the study had attracted complaints of noise and thus the matter is trivial. This assertion is, to say the least, disingenuous. Many of the developments at that time were of small turbines set in isolated areas of the countryside, well away from habitation. In addition, as noted above, the proportion of those affected by wind turbine noise who actually complain is very small. It must be emphasised that research into wind farm noise and health issues in the UK is virtually non-existent and of poor quality. To suggest that there is "no problem" when faced with the large body of evidence presented here is perverse. The conclusion is also contradicted by Moorhouse's study (vide infra) which showed a complaint rate of 20%.

3.6. Salford study

3.6.1. Nuon is likely to refer also to a report by Moorhouse and others of the University of Salford, commissioned by DEFRA into Aerodynamic Modulation of Wind Turbine Noise published in 2007. A survey was made of the local authorities responsible for wind farms in, or adjacent to, their area. 133 wind farms were identified of which 27 (20%) had attracted complaints. An attempt was made to correlate complaint logs with recorded wind speed and direction. Once again the methodology is fundamentally flawed. Complaints were solicited from local authorities and not from residents. The review was entirely theoretical with no communication with residents. The conclusions were that AM was such a minor problem that no further research was warranted.

3.6.2. The Editor of Noise Bulletin greeted the publication of the report thus:

"`New report eases concerns over wind turbine noise' trumpets the Government press release, then saying aerodynamic modulation is `not an issue for the UK's wind farm fleet'. This conclusion is not justified based on the report, and by halting further research work without transparently monitoring the wind farms subject to complaints will inflame, not ease concern of objectors ... Only when the public can trust the Government and wind farm developers on noise issues will there be a chance that the public will accept them without a fight ..."
(Pease J. *Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5).

3.6.3. On 2 August 2007, Dick Bowdler, an acoustician and member of the Noise Working Group which commissioned the report, resigned from the NWG. This highly unusual step was taken because, as his letter states:

"I have read the Salford Report and the Government Statement. As a result I feel obliged to resign from the Noise Working Group.
The Salford Report says that the aims of this study are to ascertain the prevalence of AM from UK wind farm sites, to try to gain a better understanding of the likely cause, and to establish whether further research into AM is required. This bears little relation to what we asked for which clearly set out in the minutes of the meeting in August 2006. We all knew then (as was recorded in the original notes of the meeting) that complaints concerning wind farm noise are currently the exception rather than the rule. The whole reason for needing the research was that `The trend for larger more sophisticated turbines could lead to an increase in noise from AM'.

It was not the intended purpose of the study to establish whether more research was required. We all agreed at the August 2006 meeting that such research was needed. That was precisely the outcome of the meeting. The prime purpose of what eventually became the Salford Report was to identify up to 10 potential sites which could be used to carry out objective noise measurements. The brief for the Salford report, which was never circulated to the NWG, completely ignored the NWG views.
Additionally, I find it entirely unacceptable that we are not to be told the names of the wind farms listed in the Salford report. So the only part of the report of any value to assist future research is inaccessible to those of us who would like to progress matters further.
Looking at the Government Statement it is clear that the views of the NWG (that research is needed into AM to assist the sustainable design of wind farms in the future) have never been transmitted to government and so the Statement is based on misleading information".
(*Noise Bulletin*, Issue 15, Aug/Sept. 2007 page 5)

3.6.4. If both a leading commentator in the field and a leading member of the Government's own working group have no faith in the study then its conclusions may safely be dismissed.

3.7. Kamperman comments

3.7.1. George Kamperman, (2008 personal communication) a distinguished US noise engineer, is quoted in Pierpont's book as saying, *"After the first day of digging into the wind turbine noise impact problems in different countries, it became clear the health impact on persons living within about two miles from 'wind farms' all had similar complaints and health problems. I have never seen this type of phenomenon [in] over fifty plus years of consulting on industrial noise problems. The magnitude of the impact is far above anything I have seen before at such relatively low sound levels. I can see the devastating health impact from wind turbine noise but I can only comment on the physical noise exposure. From my viewpoint we desperately need noise exposure level criteria."* Kamperman's recommended setback of at least 1km (Kamperman & James 2008) has changed to at least 2km as a result of Dr Pierpont's evidence (Kamperman 2008 personal communication). He has recently published a more detailed set of recommendations to determine setback distances (Kamperman & James 2008b).

3.8. Conclusions

3.8.1. The quality of the research in this area is low. Most are surveys using self-completed questionnaires. Response rates have generally been quite good for this type of enquiry, which may reflect the public interest and concern that wind turbines generate. Nevertheless, it is inevitable that it is more likely that those who feel they have been affected will respond rather than those who have not. The questionnaires themselves have not always have been well drafted. Most do not have a control group, a separate group not exposed to turbine noise with whom to make comparisons. The studies are all post hoc, initiated after the turbines have been operating and generally in response to complaints. The lack of pre-exposure data weakens the studies but does not invalidate them totally. Many of the authors have been criticised for their presumed lack of expertise in this area. The poor quality of the research is not surprising as government and industry have refused funding and co-operation and individuals conducting research have had to rely on their own resources.

3.8.2. In weighing the evidence, I find that, on the one hand there is a large number of reported cases of sleep disturbance and, in some cases, ill health, as a result of exposure to noise from wind turbines supported by a number of research reports that tend to confirm the validity of the anecdotal reports and provide a reasonable basis for the complaints. On the other, we have badly designed industry and government reports which seek to show that there is no problem. I find the latter unconvincing.

3.8.3. **In my expert opinion, from my knowledge of sleep physiology and a review of the available research, I have no doubt that wind turbine noise emissions cause sleep disturbance and ill health.**

4. Preventing sleep disturbance from wind turbine noise.

4.1 Background

4.1.1. Developers of noisy industrial processes, including wind turbines, seek to mitigate the disturbance by siting them in areas of high ambient noise, such as close to major roads. In the case of wind turbines, it is assumed that rising wind speed will not only increase turbine noise but ambient noise also. This is, of course, not the case if you are sheltered from the wind in your bedroom. Motorway noise diminishes at night as the volume of traffic decreases. In addition, it is common for wind speeds to diminish at ground level as night falls while being maintained at turbine hub level, wind shear (Pedersen E and Persson Waye K. 2003, Schneider 2007). In both cases, the turbine noise will be much more audible as ambient noise decreases and explains why complaints of nocturnal noise and disturbed sleep are common. The importance of wind shear has been acknowledged in a recent technical contribution to Acoustics Bulletin (March April 2009) from some members of the NWG calling for all noise levels to be referenced to wind speed at turbine hub height.

4.1.2. Schneider found that night time turbine noise was between 3 and 7dBA greater than predicted and, during periods of atmospheric stability, turbine noise was 18.9 to 22.6dBA above ambient. In addition, as noted above, the characteristics of wind turbine noise are such that it can be heard despite road noise. It should be noted that as the decibel scale is logarithmic, a 6dB increase is equivalent to a **doubling** in sound pressure level and a 12dB change is a **quadrupling**.

4.1.3. van den Berg, in a paper presented at Euronoise 2003, investigated the relationship between calculated noise generated by wind turbines and that actually measured. He confirmed that the turbines were more audible at night principally due to amplitude modulation. To quote his paper: *"As measured immission levels near the wind park Rhede show, the* *discrepancy may be very large: sound levels are up to 15 dB (!) higher than expected at 400 m from the wind park. At a distance of 1500 m actual sound levels are 18 dB higher than expected, 15 dB of this because of the higher sound emission and 3 dB because sound attenuation is less than predicted by the sound propagation model."* An 18dB increase is equivalent to an **8 fold increase** in sound pressure and a 15dB change is a **6 fold increase**. An 18dB increase is a close to a three fold increase in perceived loudness. **Calculated measures of wind turbine noise are woefully inadequate.**

4.2. Mitigation of wind turbine noise

4.2.1. Bowdler (2008) has recently reviewed the causation of the swishing and thumping noises associated with wind turbines. He concludes that, while there are several theories, no definitive mechanism can be established. It follows that industry claims to mitigate turbine noise by changing blade shape and turbine spacing should be treated with scepticism until definitive evidence of their efficacy are presented.

4.2.2. It follows that attempts to reduce wind turbine noise immissions after plant becomes operational are unlikely to be successful. Blade feathering will reduce power output, which will be opposed by the operators. The importance of assuring residents that noise limits are capable of being met before construction was emphasised by Mr Lavender, Inspector at the Thackson's Well Inquiry (APP/E2530/A/08/2073384) who stated: "securing compliance with noise limit controls at wind farms, in the event of a breach, is not as straightforward as with most other forms of noise generating development. This is because noise from turbines is affected primarily by external factors such as topography and wind strength, a characteristic that distinguishes them from many other sources of noise, such as internal combustion engines or amplified music, which can be more directly and immediately influenced by silencing equipment, insulation or operator control." It follows that application of the precautionary principle is essential where there is any possibility of noise disturbance from wind turbines.

4.2.3. Thus, the **only** mitigation for wind turbine noise is to place a sufficient distance between the turbines and places of human habitation. PPS22 advises that ETSU-R-97 *should* (author's italics) be used to estimate noise levels around turbines which taken with measurements of ambient noise can, in theory, predict noise disturbance in adjacent properties. Many expert acousticians have severely criticised ETSU-R-97, not least Mr Dick Bowdler (2007), a member of the Government's Noise Working Group considering ETSU-R-97. Its major flaws include the use of **averaged** noise levels over too long a time period and using a best fit curve, thus ignoring the louder transient noise of AM which cause awakenings and arousals. It ignores also the property of low frequency noise to be audible over greater distances than higher frequency noise. By concentrating on sound pressure alone, it ignores the increased annoyance of particular noises, especially that associated with AM. It is also the only guidance anywhere in the world which permits a **higher** sound level at night than during the day, completely contrary to common sense, noise pollution legislation and WHO guidelines.

4.2.4. Stigwood (2009) has shown that large turbines (hub heights 50-100m) are more likely than smaller turbines (hub height 30m) to cause excessive amplitude modulation, increased likelihood of low frequency noise and greater disturbance inside buildings. Internal noise can modulate over 15-20dB, changes which are easily perceived. This is probably due to different wind speeds and atmospheric conditions at these heights. He concludes that ETSU-R-97, which was developed for smaller turbines is inappropriate for large turbines.

4.2.5. Bullmore (2009) concluded that measuring wind speed at a single, low height, as required by ETSU-R-97, does not permit an accurate calculation of turbine and ambient noise.

4.2.6. Despite, or because of, ETSU-R-97, complaints of noise disturbance from industrial wind turbines continue and it is clear that ETSU-R-97 can not be relied upon to prevent sleep disturbance in those living near wind turbines.

To quote Mr Peter Hadden in evidence to the House of Lords Economic Affairs Committee:

"There is material evidence available to show that ETSU R 97 has failed to provide a reasonable level of protection to family homes from unbearable noise pollution where wind turbines are located too close to homes. Symptoms include sleep disturbances and deprivation, sometimes so severe that families are forced to evacuate their homes in order to stabilise well-being and to resume normal family life. This is a worldwide phenomenon where wind turbines are located too close to homes."

4.2.7. Planners should note also that the application of ETSU-R-97 is advisory in PPS22, not mandatory (*should* not *must*). It is also subordinate to the precautionary principle set out in PPS 23 (see below). Rather than rely on a provenly inadequate set of theoretical calculations to determine setback distance it is logical to look at the real world and the relationship between setback and noise complaints from existing sites. Human senses and opinion are used to judge visual impact. It is therefore consistent and logical to rely on human senses and opinion in respect of noise impact. Many of these sites causing problems have been in place for several years. The application by Nuon is for larger turbines than have been previously erected in the UK and thus allowance must be made for their additional noise in determining setback.

4.2.8. While it may be possible to produce a reasonable acoustically based theoretical approach to calculating set back distances (Kamperman and James 2008b), it makes more sense to rely on recommendations from observations of the effects on real people at established wind farms.

4.3. Swinford

4.3.1. The prevailing wind in South Leicestershire is from the south west and the village of Swinford is thus up wind of the proposed turbines. However, for about 20% of the year, the wind is from the north east. Under these conditions, the background noise in the village diminishes markedly as the M1/A14 and Catthorpe interchange is now down wind. Stable wind conditions with increased wind shear is equally likely to occur in any wind direction and occur to a level greater than that allowed for in ETSU-R-97.

4.3.2. Under the conditions of a north easterly wind and stable wind conditions, the residents of the village of Swinford which is only 800-1000 meters from the proposed turbines will be at much greater risk of sleep disturbance from lower than average background noise levels and greater than predicted turbine noise levels.

4.4. Conclusions

4.4.1. **Table 1** (see end of text) shows recommendations for setback distance by a number of authorities. References can be found in the Bibliography. In general, noise engineers recommend lesser setback distances than physicians. The former rely more on measured and/or calculated sound pressures and the latter on clinical reports. It is logical to prefer the actual reports of the humans subjected to the noise rather than abstract calculations, even if the latter accurately measure ambient noise and allow for the low frequency components of wind turbine noise. **Calculations can not measure annoyance and sleep disturbance, only humans can do so.**

4.4.2. A setback distance of at least 1.5km is necessary to ensure, with a reasonable degree of confidence, that the wind turbine noise will not disturb the sleep of those living in proximity to the proposed Swinford development.

5. Planning considerations

5.1. PPS22

5.1.1. PPS22 was promulgated subsequent to ETSU-R-97 and should therefore take precedence. Section 41 states: *"Development proposals should demonstrate any environmental, economic and social benefits as well as how any environmental and social impacts have been minimised through careful consideration of location, scale, design and other measures."* and *"Local planning authorities should ensure that renewable energy developments have been located and designed in such a way to minimise increases in ambient noise levels."*

5.1.2. Proposals that seek to place turbines within 1.5km of habitation have not sought to minimise environmental and social impact by wind turbine noise and its effects on sleep and health. They are therefore in contravention of PPS22.

5.1.3. The Companion Guide to PPS22 states *"RE 3 describes Factors to be considered in Planning for Wind Farms. These include: residential amenity (on noise and visual grounds); safe separation distances;"* and *"Well-specified and well-designed wind farms should be located so that increases in ambient noise levels around noise-sensitive developments are kept to acceptable levels with relation to existing background noise."*

5.1.4. Proposals that site wind turbines within 1.5km of habitation will not keep wind turbine noise to an acceptable level and are therefore in contravention of PPS22.

5.2. PPS7

5.2.1. PPS7 states:

5.2.2. *"ensuring people have decent places to live by improving the quality and sustainability of local environments and neighbourhoods"*

5.2.3. *"All development in rural areas should be well designed and inclusive, in keeping and scale with its location, and sensitive to the character of the countryside and local distinctiveness"*

5.2.4. *"have regard to the amenity of any nearby residents or other rural businesses that may be adversely affected by new types of on-farm development"*

5.2.5. Section 15 states: *"Planning authorities should continue to ensure that the quality and character of the wider countryside is protected and, where possible, enhanced."*

5.2.6. Proposals which site wind turbines within 1.5km of residential dwellings can not be said to enhance the quality of the countryside nor have regard to the amenity of local residents and must be rejected.

5.3. PPS23

5.3.1. PPS23 states:

5.3.2. *"the precautionary principle should be invoked when:*

- *there is good reason to believe that harmful effects may occur to human, animal or plant health, or to the environment*
- *the level of scientific uncertainty about the consequences or likelihood of the risk is such that best available scientific advice cannot assess the risk with sufficient confidence to inform decision-making."*

5.3.3. Application of ETSU R 97 is subordinate to the commitment to the Precautionary Principle outlined in PPS23. The objections to ETSU R 97 are so fundamental and the concerns regarding its validity so great, as is the evidence of human harm, that the precautionary principle must be invoked and consequently PPS 23 and EV/23 applied and permission refused on that account.

5.4 East Midlands Regional Spatial Strategy (RSS8)

5.4.1. Policy 41 states: *"In establishing criteria for onshore wind energy Development Plans and future Local Development Frameworks, should give particular consideration to: the effect on the built environment (including noise intrusion)."*

5.4.2. Proposals that site wind turbines within 1.5km of residential dwellings do not give sufficient consideration to the noise effects on the built environment and are therefore in contravention of RSS8.

5.5. Harborough District Local Plan

5.5.1. Harborough District Local Plan states that:

5.5.2. *"the district council will grant planning permission for the development of renewable energy schemes provided that they do not have an unacceptable impact on the landscape, features of historic and archaeological interest, nearby land use, residential amenity……."*

5.5.3. *"..proposals should not adversely affect the established character of the surrounding area in terms of scale, space around buildings, density, design, colour and texture of materials"*

5.5.4. *"...new development should not adversely affect the amenities of neighbouring users..."*

5.5.5. Policy EV/5 states: *"The district council will refuse planning permission for development proposals in the countryside unless the following criteria are met:*

- *The development does not adversely affect the character and appearance of the countryside*
- *The development does not adversely affect the amenities of the residents of the area*
- *Any new buildings are sited in a position that minimises their impact on the landscape and on important views into and out of villages"*

5.5.6. Clearly, any development which places wind turbines within 1.5km of residential dwellings will adversely affect the amenity of the residents and must be rejected.

5.5.7. Policy EV/23 states: *"the District Council will impose conditions on planning permissions to ensure that the development does not have an adverse effect on the character of its surroundings or harm the amenities of nearby users, through noise...If the District Council is not satisfied that these adverse effects would be overcome by the imposition of conditions, planning permission will not be granted"*

5.5.8. The evidence presented in this paper provides incontrovertible proof that wind turbines emit levels of noise harmful to human health and wellbeing. ETSU R 97 does not provide sufficient protection for residents as has been amply demonstrated by several leading researchers.

5.6 Leicestershire, Leicester and Rutland Structure Plan 1996-2016 Resource Management Policy 1

5.6.1. LLRSP 1996-2016 states: *"All new development will minimise or avoid air, noise, water, land and light pollution"*

5.6.2. Developments within 1.5km of residential dwellings engender several types of pollution: noise, light (the likelihood of aviation lights) and shadow flicker, and will certainly not be minimised.

6. Overall Conclusions

7.1. The only mitigation of sleep disturbance from industrial wind turbine noise is a setback of at least 1.5km and probably greater. This estimate is based on data from present installations, many of which have a much smaller rated capacity than those proposed by Nuon. Most of the village of Swinford as well as outlying properties are within 1-1.5km of the proposed site and there is therefore a very high risk that a large proportion of residents would be adversely affected. **The application must be rejected.**

CD Hanning

14th June 2009

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Figure 1. Sound level and annoyance for different noise sources (van den Berg 2008)

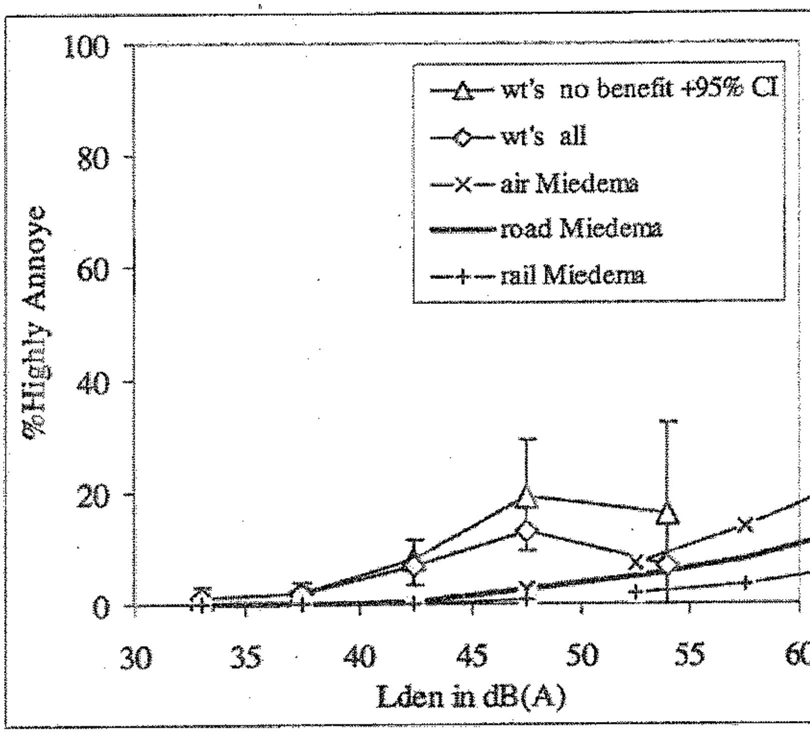
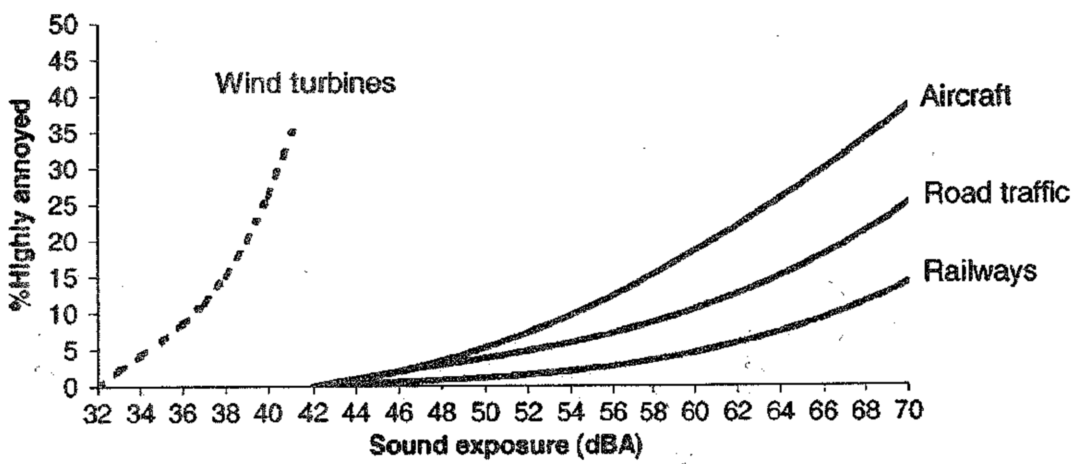


Figure 8.1: relation between sound level Lden and percentage highly annoyed residents exposed to that sound, for three transportation noise sources and for wind turbines; the relation is given for all respondents and for those that have no economical benefit from a wind turbine.

Bars denote 95% confidence interval for non-benefitters.

Figure 2. Sound level and annoyance for different noise sources (Pedersen E and Persson Waye, 2004)



Sound exposure is for wind turbines calculated A-weighted L_{eq} for a hypothetical time period and for transportation DNL.

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Table 1. Recommendations for setback of residential properties from industrial wind turbines

Note 1. The 2km limit from edges of towns and villages seems to have been set more for visual than noise reasons

Authority	Year	Notes	Recommendation	
			Miles	Kilometres
Frey & Hadden	2007	Scientists. Turbines >2MW	>1.24	>2
Frey & Hadden	2007	Scientists. Turbines <2MW	1.24	2
Harry	2007	UK Physician	1.5	2.4
Pierpont	2008	US Physician	1.5	2.4
Welsh Affairs Select Committee	1994	Recommendation for smaller turbines	0.93	1.5
Scottish Executive	2007	See note 1.	1.24	2
Adams	2008	US Lawyer	1.55	2.5
Bowdler	2007	UK Noise engineer	1.24	2
French National Academy of Medicine	2006	French physicians	0.93	1.5
The Noise Association	2006	UK scientists	1	1.6
Kamperman & James	2008	US Noise engineers	>.62	>1
Kamperman	2008	US Noise engineer	>1.24	>2
Bennett	2008	NZ Scientist	>0.93	>1.5
Acoustic Ecology Institute	2009	US Noise engineers	0.93	1.5