Fourth International Meeting on Wind Turbine Noise

Rome Italy 12-14 April 2011

An overview of residential health effects in relation to wind turbine noise

Frits van den Berg
GGD - Amsterdam Public Health Service,
P.O. Box 2200, 1000 CE Amsterdam, the Netherlands
fvdberg@ggd.amsterdam.nl

Abstract

Noise generally affects people in a number of ways. Being annoyed and disturbed in sleep are the most common effects as they can occur at relatively low sound levels. Effects on blood pressure, learning/performance and stress and psychological effects are to some extent a result of annoyance and sleep disturbance and mostly occur at higher sound levels. Though wind turbines are relatively low level sources (compared to busy roads or airports) moderate health effects are observed. These effects can be related to acoustic (level, sound character, time pattern), non-acoustic (economic returns, visibility, unpredictability, attitude), personal (health, age, noise sensitivity) and social (justice, attitude) factors.

Introduction

This paper is a shortened and adapted version of a chapter on health effects in a new book on wind turbine noise, edited by Dick Bowdler and Geoff Leventhall. In contrast to the book, less attention will be given here to the relations between wind turbine noise level and annoyance and sleep disturbance as these have been dealt with in earlier papers (van den Berg, 2009; Janssen et al, 2009) and a report by Janssen et al (2008). The focus of this paper are other health effects that are mentioned in connection to wind turbine noise.

The definition of health of the World Health Organization is “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. An adverse health effect can thus be defined as a negative impact on the physical, mental and social well-being of a person or group of persons. In general a number of adverse health effects of noise are distinguished (WHO, 2000):

- hearing impairment
- interference with speech communication
- cardiovascular and physiological effects
- sleep disturbance
- mental health effects

- effects on performance
- effects on residential behaviour and annoyance

Wind turbines are a relatively low level source (compared to, *e.g.*, a nearby busy road or airport). High level effects such as hearing impairment and cardiovascular effects are thus not expected. The health effects that do occur are related to acoustical factors such as noise level and the character of the noise, and to non-acoustical factors such as visibility and attitude.

Acoustical factors related to the impact of wind turbine noise

Visual impact and noise are the most frequently reported problem in relation to wind turbines or wind farms (Devine-Wright, 2005). The dominant negative effect of noise on residents is annoyance. There is an indication that sleep disturbance may be a second important noise effect, but there is as yet little information available.

Sound character and annoyance

When comparing the dose-response curves for wind turbine noise annoyance to similar curves for other noise sources, wind turbines appear to be a relatively annoying noise source. Dose-response relations have been determined for the dominant transportation modes (road, rail and air transport) and for industrial sources, including railway shunting yards, by Miedema and Oudshoorn (2001) and Miedema and Vos (2004). Figure 1 shows that wind turbine noise (black curve) is more annoying than the other sources with the exception of shunting yards. There are several acoustical and non-acoustical factors that could explain this relatively annoying character. Human hearing is relatively sensitive to the regular variation or amplitude modulation ('swishing' or 'beating') present in wind turbine sound. The evaluation of a sound that can be picked up easily will (also) depend on its character: if it is unwanted, this character will aggravate its disturbing character. Laboratory studies show that amplitude modulation of a broad band sound, either with or without a strong low frequency component, increases its annoyance but not its perceived loudness. The increase in annoyance due to modulation corresponds to an increase of the level of the unmodulated sound of at least 3 dB. If the sound character is taken into account and a 5 dB penalty is added to the sound level of wind turbines because of the presence of amplitude modulation, the curve for wind turbine noise are within the range of the main sources at Lden levels below 50 dB(A) as shown by the grey curve in figure 1.

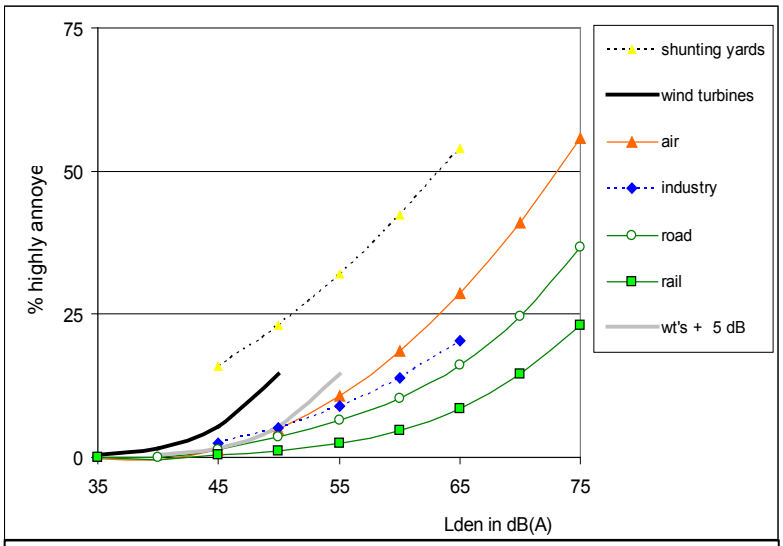

Figure 1: percentages of respondents that are highly annoyed when exposed indoors to noise from wind turbines or other

Several publications point to the low frequency character of wind turbine noise as an aggravating factor. Wind turbines indeed produce a substantial amount of low frequency sound energy. However, as the A-weighting mimics the frequency dependency of human hearing at low to moderate loudness, A-weighting should be a correct estimate of the loudness of wind turbine sound (which has a low to moderate level). The noise impact of wind turbines is dominated by frequencies of approximately 100 to 1000 Hz. There is a steep decrease in A-weighted level when the octave band frequency decreases below 63 Hz and this decrease continues down to 4 Hz (Van den Berg et al, 2008 and Søndergaard et al, 2007). Jakobsen (2005) reviewed all published measurements of infrasound from wind turbines and concluded that at a distance of 100 m all measured infrasound levels at a distance of 100 m from a single turbine (with an upwind rotor),were 25 dB or more below the average hearing threshold. He concluded that the A-weighted sound level was a likelier candidate to explain at least part of the annoyance as this 'normal' sound exceeded the Danish noise limit in most cases. This was supported by Van den Berg (2004) who also concluded that infrasound due to the passing wind turbine blades must be considered inaudible, that the calculated sound levels were underestimated and that the blade passing frequency does modulate well audible, higher frequency sounds and thus creates periodic (AM) sound that could be an important cause of annoyance (Van den Berg, 2005). The fact that a modulation frequency is also expressed in Hz may have led to confuse this with infrasound frequencies.

This conclusion may not hold for future developments: Pedersen and Møller (2010) have shown that with increasing electric power of wind turbines their sound power increases somewhat faster and the low frequency part of the sound (10 – 160 Hz) still faster. The differences are small (up to 3 dB) but are expected to grow with the development of more powerful wind turbines.

The view that *inaudible* infrasound can have (adverse) effects on people is not supported by studies investigating the effect of low levels of low frequency sound (Yamada et al, 1983; Takahashi, 2009). Also, in their evolution human beings have been exposed to low frequency pressure fluctuations from turbulence in wind. These fluctuations can be heard as 'wind noise' (where the auricle may also induce extra turbulence) and can be felt on the skin. Expressed as a (sound) pressure level, for wind velocities of 4 m/s (3 Beaufort) and higher the one-third octave band levels of these fluctuations are 60 dB or higher at frequencies below 50 Hz (Van den Berg, 2006b). It seems plausible that this would have the same effect as exposure to noisy (non-tonal) low frequency sound/infrasound.

Thus, as yet there is no basis to state that inaudible (low frequency) sound can have somatic effects. To investigate this further clear indications to the contrary are needed rather than speculations.

Sleep disturbance

Janssen et al (2008) have shown there is a significant relation between being disturbed in sleep at least once a month and the wind turbine sound level on the façade. This relation has been analyzed further by Bakker et al (2011) with the Dutch wind turbine noise survey data (Pedersen et al, 2009) for respondents without economic benefits from wind turbines. For those who had not heard wind turbine sound at their home (and were thus not annoyed), there was no significant influence

of the sound level on sleep disturbance -as one would expect when the sound is not audible. For this group, sleep disturbance and age were related significantly. A further analysis was applied to respondents who stated they could hear the sound from wind turbines at their home, no matter whether they were or were not annoyed by the sound. This showed that in the quiet rural area (no built-up area, no main road within 500 m from the nearest wind turbine) a higher sound level from wind turbines led to a significantly higher percentage of annoyed residents and the annoyance in turn led to significant more sleep disturbance. In this analysis the direct relation between sound level and sleep disturbance was not significant, indicating that it may be the annoyance rather than the sound as such that leads to more sleep disturbance. These relations were weaker and less significant for the population in the noisier area types (in a built-up area or with a main road within 500 m from the nearest wind turbine): here only annoyance and sleep disturbance were significantly related and the sound level did not influence either annoyance or sleep disturbance in a significant way. Possibly the impact of wind turbines is less dominant in these noisier areas. These results show that audible noise can lead to annoyance and the annoyance aggravates sleep problems.

Non-acoustical factors related to the impact of wind turbine noise

Several non-acoustical factors have been found to influence the relation between wind turbine sound and annoyance.

Economic benefit

Little annoyance with sound from wind turbines was reported by residents if they had economical benefits from wind energy even though these residents were on average exposed to higher sound levels. Also, those benefiting economically from wind turbines felt significantly less disturbed in their sleep by noise. However, there was no difference in the ability to hear the sound between respondents that benefited economically from wind turbines and those who did not.

Influence of visibility

Respondents that could see at least one wind turbine from their dwelling were more likely to be annoyed by the sound than those who did not see any wind turbines (Pedersen et al, 2009). When respondents did not see wind turbines, the turbines were either relatively small, i.e. distant, or respondents lived in built-up areas. When the sight of the wind farm was blocked, then the sound could be (partly) blocked too, leading to lower sound levels, which could possibly explain the lower levels of annoyance. Alternatively, the enhanced annoyance when the wind turbines were visible could also be due to a multimodal effect: the rotating blades of a wind turbine attracting attention could increase the awareness of the sound and hence also the possibility of noise annoyance (Pedersen et al, 2007).

Predictability and control

The level of wind turbine sound varies unpredictably within a relatively short time span (minutes to hours). Although the sound level of modern, tall wind turbines may at night be lower for part of the time, it usually is either higher or does not change clearly at night. This was confirmed in the Dutch survey (Pedersen et al, 2009) where

only a small proportion of respondents reported hearing wind turbine sound less clearly at night. In this respect wind turbine sound is different from traffic noise or industrial noise that usually return to lower levels at night. As a consequence residents that are bothered by wind turbine sound are never sure whether the sound at night will allow them to be at home without being disturbed.

According to Taylor (1997) a healthy environment “provides safety, opportunities for social integration, and the ability to predict and/or control aspects of that environment”. In the Dutch survey there was little annoyance amongst respondents with an economical benefit of wind turbines. One of the reasons may be that they have more control over the wind turbines: most of them have taken part in the decision to put up the turbines and they can stop them if they want.

Attitude and fairness

Residents that benefited economically from wind turbines and those that did not had different opinions on wind farms and these were related to different views on landscape utility and use (Pedersen et al, 2009). In the Dutch survey a negative attitude towards the wind turbines, especially with regard to the impact on landscape, was associated with annoyance with wind turbine sound. Annoyance was also correlated with changes for the worse in the living environment as perceived by respondents (but not with changes for the better). A strong correlation between noise annoyance and a negative opinion of the impact of wind turbines on the landscape was found in earlier studies and confirmed in the Dutch survey. The theory of ‘place attachment’ may explain this correlation. In this theory, a new technical device that is perceived as not being beneficial for the living environment induces a negative reaction (Pedersen et al, 2009).

From a review Tyler (2000) concluded that people are more willing to accept decisions when they feel that those decisions are made through decision-making procedures they view as fair. People evaluate a procedure as fair when all parties at stake have opportunities to participate, the authorities are neutral, the motives of the authorities are trusted, and people are treated with dignity and respect in the process. This fairness can influence noise annoyance as Maris et al (2007) have shown. In a laboratory experiment participants were exposed to medium or loud aircraft noise (50 and 70 dB(A)). Part of the participants could give their preference for one of three sound samples (many short or some long overflights, or in between) to be played when doing a task, others were not asked. In fact, the same sample was presented to all participants. Results showed that annoyance ratings were significantly lower when a preference could be given compared to the situation this was not asked, though this was found only at the exposure level of 70 dB(A). Thus, at a high noise level a ‘fair procedure’ can reduce noise annoyance.

Wolsink and Breukers (2010) compared the development of wind energy in three regions (Northrhein Westfalia, the Netherlands and England) and found that “an approach that focuses on implementing as much wind power as possible, relying on technocratic reasoning and hierarchical policies is in practice the least successful, whereas collaborative perspectives with more emphasis on local issues and less on the interests of the conventional energy sector were particularly dominant in the most successful case”.

Personal and social factors

Several individual factors have a clear influence on annoyance from a noise source. Most important are fear in relation to the noise source and sensitivity to noise. For rail, road and aircraft noise Miedema and Vos (1999) have related these factors to the reported annoyance, using a database containing the response to noise surveys from nearly 50000 subjects. The results could be expressed as an increase or decrease in annoyance due to each factor, or as an equivalent increase or decrease in noise level. Fear associated with the noise source was found to have a significant and large impact on annoyance. When dividing respondents into three groups, the difference between the group with lowest and highest fear was equivalent to a difference in sound level (Ldn) of up to 19 dB. The authors point out that the added annoyance could be associated with actual fear of that source or it could be related to a predisposition of respondents to noise annoyance and fear.

A second important factor is noise sensitivity. Again dividing respondents into three groups, the difference in annoyance between groups with lowest and highest sensitivity was equivalent to a difference in sound level (Ldn) of approximately 11 dB. Age also had a relation with noise annoyance, but less pronounced than fear or noise sensitivity: at the same sound level younger and elderly people are less easily annoyed than people of intermediate age. Education level, occupational status, the number of persons in a household, home-ownership, economic dependency on the noise source and use of the noise source (car, train or airplane) each had a small or very small effect on annoyance. There was no relation between noise annoyance and gender.

Flindell and Stallen (1999) reviewed non-acoustical factors that may have an effect on noise annoyance. Apart from personal benefits, predictability, (perceived) control and noise sensitivity they also lmentioned:

- trust and recognition that impacts are recognised by authorities;
- the ability of people to speak to and be listened to by authorities;
- general attitudes, such as awareness of economic and social benefits of the noise source, awareness of noise control action costs, fear of crashes, etc;
- compensation, such as noise insulation or house purchase schemes;
- home ownership: home owners might be concerned about the value of their property;
- accessibility to information: this can affect the extent to which authorities are perceived to be taking an interest in the noise exposed community;
- understanding; attitudes can be based on irrelevant or incorrect information.

Other health effects (possibly) related to wind turbine noise

Irritability or annoyance and sleep disturbance are common effects of noise because they occur at relatively low noise levels and thus are bound to come up first. On the other hand, hearing impairment and cardiovascular effects are adverse health effects that occur at relatively high levels only and are –at least as yet- not relevant when considering wind turbine noise. Other effects that are associated with noise (WHO, 2000) are effects on communication by speech, mental health, performance and behaviour.

Speech communication

For vocal communication a threshold level is given above which effects may occur at home and in school. A threshold noise level of 35 dB(A) enables people to understand one another at close distance (1 meter) without having to raise their voice. Assuming a façade sound insulation of at least 15 dB, this means that effortless speech is possible at outdoor sound levels of 50 dB(A) and possibly higher.

Mental health, performance and behaviour

It is clear that sound can have effects on mental well-being. The level of the sound may be less important than the information content of the sound: where does the sound come from, what does it mean? Even sounds that are not audible to others can have a profound influence on people's well-being and in general their quality of life. Several studies have shown that the impact of tinnitus or aural hallucinations is highly influenced by feelings of fear (Van den Berg, 2009b).

Although we know from everyday life how sound can affect us mentally, not much research has been published on the adverse mental effects of noise and the results are not straightforward. According to the WHO (2000) environmental noise can have various mental effects such as effects on anxiety, emotional stress, nervous complaints, nausea, headaches, mood changes and social conflicts. It can also have an effect on psychiatric disorders such as neurosis, psychosis and hysteria. As we know, noise –for example from a neighbour- can drive a person crazy, though of course we usually do not really mean the sound causes mental insanity. But it does mean that the effect can be very serious.

There are two studies on mental health in relation to wind turbine noise. Pedersen (2011) analyzed the results of three (two Swedish and one Dutch) wind turbine noise surveys and found that health variables and wellbeing were not consistently related to the sound levels for all studies. Tinnitus and diabetes were positively related to the sound levels in one survey each, but not in the other studies. However, several measures of stress were associated with annoyance due to wind turbine noise: feeling tense or stressed and feeling irritable was associated with noise annoyance in all three studies. Headache was associated with annoyance in two of the three studies and undue tiredness in one study only.

Bakker et al (2011) analyzed in more detail the Dutch wind turbine noise survey data for noise in relation to sleep disturbance and non-specific psychological distress. Distress was assessed with the 12-item version of the General Health Questionnaire which is designed to detect psychiatric disorders in community samples and non-psychiatric clinical settings. For those who had not heard wind turbine sound at their home, sleep disturbance, psychological distress and age were interrelated significantly, but there was no significant influence of the wind turbine sound level (as one would expect when the sound is not audible). For respondents without economic benefits from wind turbines and who could hear the sound from wind turbines at their home the analysis showed that in the quiet rural area a higher sound level from wind turbines led to a significantly higher percentage of annoyed residents and the annoyance in turn led to significantly more psychological distress (as well as sleep disturbance, which was in itself related to distress). The direct relation between

sound level and psychological distress was not significant, indicating that it is the annoyance and sleep disturbance rather than the sound as such that may lead to more distress. These relations were weaker and less significant for the population in the noisier areas (built-up areas and rural areas with a main road less than 500 m from the closest wind turbine): here psychological distress was not significantly related to annoyance or sleep disturbance (and not to sound level). It thus appears that audible noise may lead to annoyance and the annoyance as well as sleep problems, partly as a result of annoyance, aggravate psychological distress.

Studies investigating other noise sources could help to understand the relation between noise and mental health. In a laboratory study with young adults Standing and Stace (1980) investigated the effect of low, medium and high sound levels of white noise on the outcome of several psychological tests. One test measured State-anxiety that assesses the individual's current level of anxiety, whereas Trait-anxiety reflects the usual feeling of anxiousness as an individual characteristic. The results showed that in the very noisy condition State-anxiety was significantly higher than in the quiet or noisy condition while Trait-anxiety did not change. Also, the variability of the State-anxiety scores (and not the Trait-anxiety scores) increased significantly for both the noisy and very noisy condition, implying that the degree to which test persons were affected spread over a wider range when noise level increased. Although the persons differed in their baseline anxiety (as measured with the Trait-anxiety score), the increase in anxiety was similar for those with the lowest scores when compared to the others. In another study following British men of 50 to 64 years of age over a period of five years (Stansfeld et al, 1996) no clear relation between the level of road traffic noise and the prevalence of minor psychiatric disorders (as determined with the General Health Questionnaire) was found, but there was some evidence for an increase in anxiety. The authors concluded that the study confirmed the results of previous studies: environmental noise does not appear to be an important cause of overall psychiatric disorder but it can contribute to feelings of anxiety.

VVVD

According to Pierpont the (infra)sound of wind turbines can cause Visceral Vibration Vestibular Disease (VVVD). This is a new diagnosis characterized by the following symptoms: "a feeling of internal pulsation, quivering or jitteriness, and it is accompanied by nervousness, anxiety, fear, a compulsion to flee or check the environment for safety, nausea, chest tightness, and tachycardia" (Pierpont, 2009). These symptoms are well/known when persons are put under stress and thus may not be specific to the impact of wind turbines. Common symptoms of excess stress include sleep disturbances, muscle tension, headache, gastrointestinal disturbances, fatigue, nervousness, anxiety, changes in eating habits including overeating, loss of enthusiasm or energy, and mood changes (Medicine Net, 2010). The degree of stress a person experiences depends upon the stressor itself, but also upon a number of individual factors such as physical health, the quality of relationships, the number of commitments and responsibilities, the degree of others' dependence and the amount of support from others, expectations, and the number of changes or traumatic events that have recently occurred in a person's live (Medicine Net, 2010).

The fourth version of the Diagnostic and Statistical Manual of Mental Disorders (abbreviated to DSM-IV) lists a number of disorders that are related to stress. Here disorder is a neutral medical term referring to a disturbance of a 'normal', healthy state. There are three anxiety disorders that possibly could occur in people who attribute their suffering to a wind turbine or wind farm: adjustment disorder, panic disorder and generalized anxiety disorder.

An adjustment disorder is a disturbance of normal, healthy functioning that can occur when a person experiences an important negative change in his or her situation or life. According to DSM-IV (1994) the main criteria for an adjustment disorder are:

- Emotional or behavioral symptoms develop in response to an identifiable stressor within 3 months of the onset of the stressor.
- The symptoms are clinically significant:
  1. there is marked distress in excess of what would be expected from exposure to the stressor; and/or
  2. there is significant impairment in social or occupational (academic) functioning
- When the stressor has terminated, the symptoms vanish within six months.

Second, a major life stress can cause panic attacks: surges of intense fear or discomfort. The panic is probably not a result of only one cause, but the result of a combination of biological vulnerabilities, ways of thinking and social stressors. Panic attack symptoms include trembling or shaking, a fear of losing control, fear of dying, a need to escape, nausea, chest pains and a racing or pounding heartbeat (Medicine Net, 2010). A panic attack as such is not necessarily a disorder. However, when panic attacks recur unexpectedly and are followed by a period of concern about additional attacks and/or the implications or consequences of an attack (such as losing control, having a heart attack, "going crazy"), and/or a significant change in behaviour related to the attacks it may be a panic disorder (DSM-IV, 1994).

Finally, people with a generalized anxiety disorder (GAD) are more vulnerable to stress and hence may react stronger than others to a stressor. Symptoms of a GAD include trembling, restlessness or a feeling of being "edgy", excessive worry and tension, an unrealistic view of problems, nausea and muscle tension and these may become worse during periods of stress (Medicine Net, 2010).

Of course, the above cannot serve as a diagnosis for people reacting strongly to the presence of wind turbines, but it does show that a psychological view on the symptoms may help to understand such reactions. If these symptoms comply with an existing diagnosis, there is no need for a new diagnosis.

If Pierpont's selection procedure would be applied to other sources of noise one will probably find similar results: there are also people that suffer from, for example, the sound of aircraft, neighbours, barking dogs or untraceable hums. The selection procedure is bound to find people who suffer the most, for whatever reason. It is possible that selected people are by their nature above-average anxious and are thus most sensitive to what they feel is an intrusion of their home.

VAD

According to Alves-Pereira and Castelo Branco (2007a) the infrasound and low frequency sound of a wind turbine can cause Vibroacoustic Disease (VAD). They postulated that at least some of the effects of sound from a wind turbine on residents

could be qualitatively explained by low frequency sound (including infrasound). Marciniak et al (1999) stated that VAD is caused by long term (10 years or more) exposure to high noise levels (at least 90 dB) at low frequencies (below 500 Hz), when it cannot be explained by other possible causes. They found VAD, identified by a thickening of the mitral valve (one of the valves in the heart) and the pericardium (a sac containing the heart), in aeronautical workers who were exposed to high sound levels over long periods of time. Several years later Alves-Pereira and Castelo Branco (2007a) stated it was not clear at what sound level VAD can occur and dose-response relations for infrasound and low frequency noise did not exist and thus the risk for developing VAD cannot be assessed. Nevertheless, in their investigation of a family with two wind turbines at 322 and 642 m from the dwelling (Alves-Pereira and Castelo Branco, 2007b), they concluded that VAD occurred and was caused by low frequency sound. The measured noise levels were substantially lower (20 dB or more) than levels at which VAD was thought to occur by Marciniak et al (1999) and the spectral levels were below the normal hearing threshold for a considerable range of frequencies in this range. If the same sound energy would be presented at the best audible frequencies, it would not cause hearing damage although the ear is the most sensitive organ. It is therefore highly unlikely that the sound as such could have effected physiological damage. Of course the sound and sight of the wind turbines could have disturbed the family.

Conclusion

Wind turbine noise appears to be a relatively disturbing sound when compared to other major noise sources. Acoustical and non-acoustical factors may explain this. Perhaps most important is the swishing or beating character of the sound. Its unpredictability, the perceived lack of control and the perceived balance of advantages and disadvantages are other relevant factors related to the annoyance from wind turbine sound (and sight). Sleep disturbance is a second important health effect to consider, but more research is needed to quantify the relation between this effect and wind turbine noise.

Measures to mitigate noise annoyance from wind turbines are reducing the sound level at the dwellings of residents, especially at night, and decreasing the modulation level. Changing the meaning of the sound can have a significant impact. If procedures and the distribution of pros and cons are perceived as just by residents, they will probably have a less negative evaluation of the sound.

References

M. Alves-Pereira, N.A.A. Castelo Branco (2007a), Public health and noise exposure: the importance of low frequency noise, proc. Internoise2007, Istanbul

M. Alves-Pereira, N.A.A. Castelo Branco (2007b), In-Home Wind Turbine Noise Is Conducive to Vibroacoustic Disease, proc. Wind Turbine Noise, Lyon

R.H. Bakker, E. Pedersen, W. Lok, G.P. van den Berg, R.E. Stewart, J. Bouma (2011), Effects of wind turbine sound on health and psychological distress, to be submitted

P. Devine-Wright (2005) 'Beyond NIMBYism: Towards an integrated framework for understanding public perceptions of wind energy', Wind Energy, vol 8, pp125–139

DSM-IV (1994), Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, American Psychiatric Association (a slightly updated version is the Text Revision (DSMIV-TR, 2000)

I.H. Flindell, P.J.M. Stallen (1999), Non-acoustical factors in environmental noise, Noise & Health, vol. 1 (3), pp. 11-16

J. Jakobsen (2005), Infrasound Emission from Wind Turbines, Journal of Low Frequency Noise, Vibration and Active Control, vol. 24 (3), pp. 145 – 155

S.A. Janssen, H. Vos, A.R. Eisses, E. Pedersen (2009), Exposure-response relationships for annoyance by wind turbine noise: a comparison with other stationary sources, proc. of Internoise2009, Edinburgh, October 26-28

S.A. Janssen, H. Vos, A.R. Eisses (2008), Hinder door geluid van windturbines: dosis-effectrelaties op basis van Nederlandse en Zweedse gegevens (Annoyance from wind turbine sound: dose-effect relations based on Dutch and Swedish data – in Dutch), TNO-report 2008-D-R1051/B, Delft

W. Marciniak, E. Rodriguez, K. Olszowska, O. Atkov, I. Botvin, A. Araujo, F. Pais, C. Soares Ribeiro, A. Bordalo, J. Loureiro, E. Prazeres De Sá, D. Ferreira, M.S. Castelo Branco, N.A. Castelo Branco (1999), Echocardiographic evaluation in 485 aeronautical workers exposed to different noise environments, Aviat Space Environ Med.vol. 70(3 Pt 2), pp. 46-53.

E. Maris, P.J. Stallen, R. Vermunt, H. Steensma (2007), Noise within the social context: Annoyance reduction through fair procedures, Journal of the Acoustical Society of America, vol. 121 (4), pp. 2000–2010, pp. 117-125

Medicine Net (consulted 14-1-2011), www.medicinenet.com, MedicineNet Inc., San Clemente California

H.M.E. Miedema, C. G.M. Oudshoorn (2001), Annoyance from Transportation Noise: Relationships with Exposure Metrics DNL and DENL and Their Confidence Intervals, Environmental Health Perspectives, vol. 109 (4), pp. 409-416

H.M.E. Miedema, H. Vos (1999), Demographic and attitudinal factors that modify annoyance from transportation noise, Journal of the Acoustical Society of America, vol. 105 (6), pp. 3336-3344

H.M.E. Miedema, H. Vos (2004), Noise annoyance from stationary sources: Relationships with exposure metric day–evening–night level (DENL) and their confidence intervals, Journal of the Acoustical Society of America, vol. 116 (1), pp. 334-343

C. S. Pedersen, H. Møller (2010), An analysis of low frequency noise from large wind turbines, proc. 14th Int. Meeting on Low Frequency Noise and Vibration and its Control, Aalborg

E. Pedersen, LR-M. Hallberg, K. P. Waye (2007), Living in the Vicinity of Wind Turbines — A Grounded Theory Study, Qualitative Research in Psychology, Vol. 4 (1), pp 49 – 63

E. Pedersen, F. van den Berg, R. Bakker, J. Bouma (2009), Response to noise from modern wind farms in The Netherlands, Journal of the Acoustical Society of America vol. 126 (2), pp. 634-643

E. Pedersen (2011), Health aspects associated with wind turbine noise – results from three field studies, accepted by Noise Control Engineering Journal

N. Pierpont (2009), Wind Turbine Syndrome – A report on a natural experiment, K-Selected Books, Santa Fe, USA

B. Søndergaard, D. Hoffmeyer, B. Plovsing (2007), Low frequency noise from large wind turbines, proc. 2nd Int. Meeting on Wind Turbine Noise, Lyon

L. Standing, G. Stace (1980), The effects of environmental noise on anxiety level, Journal of General Psychology, vol. 103, pp. 263-272

S. Stansfeld, J. Gallacher, W. Babisch, M. Shipley (1996), Road traffic noise and psychiatric disorder: prospective findings from the Caerphilly study, British Medical Journal vol. 313 (7052), pp. 266-

Y. Takahashi (2009), Vibratory Sensation Induced by Low-Frequency Noise: A Pilot Study on the Threshold Level, Journal of Low Frequency Noise, Vibration and Active Control, vol. 28 (4), pp. 245 – 253

S.E. Taylor, R.L. Repetti (1997), Health psychology: what is an unhealthy environment and how does it get under the skin?, Annual Review of Psychology, vol. 48, pp. 411-447

T.R. Tyler (2000), Social Justice: Outcome and Procedure, International Journal of Psychology, vol. 35 (2),

G.P. van den Berg (2005), The beat is getting stronger: the effect of atmospheric stability on low frequency modulated sound of wind turbines, Journal of Low frequency noise, vibration, and active control, Vol. 24(1)

G.P. van den Berg (2006a), The sounds of high winds (doctoral thesis), University of Groningen, Groningen

G. P. van den Berg (2006b), Wind-induced noise in a screened microphone, Journal of the Acoustical Society of America, vol. 119 (2), pp. 824-833

F. van den Berg, E. Pedersen, J. Bouma, R. Bakker (2008), WINDFARMperception: Visual and acoustic impact of wind turbine of wind turbine farms on residents. Report FP6-2005-Science-and-Society-20. University of Groningen and Göteborg University

F. van den Berg (2009), Why is wind turbine noise noisier than other noise?, proc. of Euronoise 2009, Edinburgh

F. van den Berg (2009b), Low Frequency Noise and phantom sounds, Journal of Low Frequency Noise, Vibration and Active Control, vol. 28 (2), pp. 105-116

WHO (2000), Guidelines for Community Noise, World Health Organization (Geneva) and Institute of Environmental Epidemiology (Singapore)

M. Wolsink, S. Breukers (2010), Contrasting the core beliefs regarding the effective implementation of wind power -an international study of stakeholder perspectives, Journal of Environmental Planning and Management, vol. 53 (5), pp. 535–558

S. Yamada, M. Ikuji, S. Fujikata, T. Watanabe, T. Kosaka (1983), Body sensations of low frequency noise of ordinary persons and profoundly deaf persons. Journal of Low Frequency Noise and Vibration, vol. 2, pp. 32-36.