Fact Sheet: Wind Turbines and Low Frequency Sound

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"There are no direct pathological effects from wind farms and…any potential impact on humans can be minimised by following existing planning guidelines". (NHMRC, 2010)

Sound basics

Sounds are waves that travel through a physical medium (e.g. air) by pressure fluctuations. When these fluctuations reach the eardrum they are converted to mechanical waves, amplified across the middle ear and converted to electrical signals by hair-like nerve cells in the inner ear. These signals are then processed by the brain and perceived as a sound.

Sound is typically measured as either "Sound Power Level" – a measure of the total acoustic power emitted by a source, or "Sound Pressure Level" – a measure of the sound (air) pressure at a receiver (microphone, eardrum, etc).

Sound is typically given in Decibels by comparing with the pressure variation corresponding to the threshold of hearing (0 dB).

Sound frequencies are measured in hertz (Hz) or cycles per second. Frequencies in the range of 20Hz to 20,000Hz are generally audible to the human ear, and each person perceives sound slightly differently. However, the ear perceives the amplitude of sound at different frequencies in a non-linear way. For example the threshold of hearing at low frequencies is about 70dB and higher. This is why sound power is often given by a logarithmic scale.

Sound is measured as Sound Pressure Level by a microphone. In order to reflect the human ear's response to changes in sound, microphones are usually equipped with filters that give different weightings to different frequencies. The important filters for wind turbine sound are:

- A-Weighting: This is the most common scale for assessing environmental and occupational sound. It approximates the response of human hearing to sounds of medium intensity.
- C-Weighting: Approximates response of human hearing to loud sounds. It can be used for low-frequency sound.
- G-Weighting: Designed for infrasound

The weighting used is denoted in the units, e.g. A-Weighted sound is given as dB(A).

An important phenomenon is that perceived change in sound level is different for different frequencies. For example at 1000 Hz a 10 dB increase is perceived as a doubling of sound, whereas at 20 Hz a 5 dB increase is perceived as a doubling of sound. This is particularly important as small changes in amplitude at low frequencies generate a large change in apparent sound.

There is a difference between infrasound and low frequency sound. Infrasound is sound that is generally inaudible to the human ear, <20 Hz, however it may still interact with the body and may be felt as vibrations. Low frequency sound is considered audible but only at high amplitudes. Low frequency sound is commonly considered to be in the range of 20 - 200Hz.

Sound from Wind Turbines

Wind turbines like all other mechanical equipment generate sound. A relative comparison of the sound from a wind turbine at 350m is given in Table 1, figures are Sound Pressure Levels. The sound generated by a wind turbine covers a broad spectrum of frequencies including infrasound and low frequency.

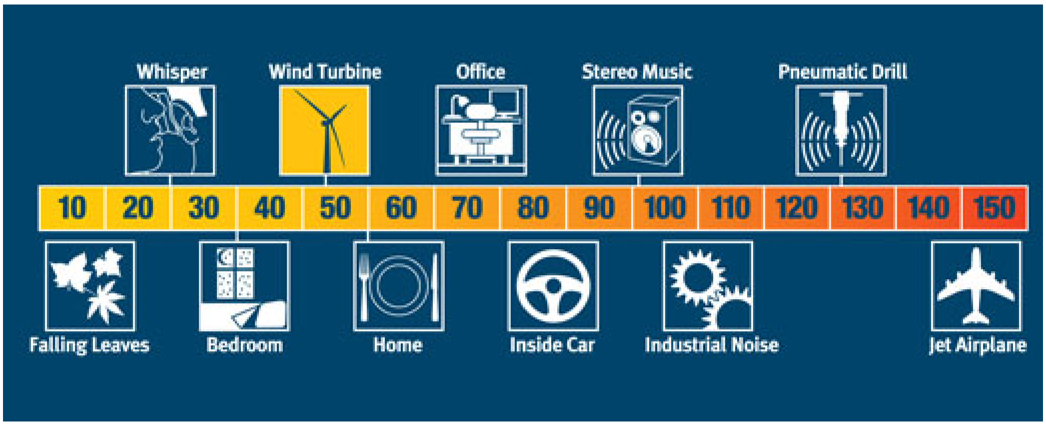

Figure 1: Sound pressure levels of wind turbine compared to other common sources (www.canwea.ca/wind-energy/myths_e.php)

Sound from wind turbines is measured according to a detailed international standard. Government planning requirements around the world require the sound from wind farms to be kept to very low levels at all nearby dwellings. For example in Victoria wind farms must not emit a sound pressure level above 40 dBA at a nearby dwelling, or 5 dBA above background noise. Wind farms use software to keep the sound levels below these limits, which involves calculating the sound at nearby dwellings while taking into account environmental conditions and background noise levels. Victoria's sound limits are some of the strongest in the world and are more stringent than the World Health Organisation's recommended value of 45 dBA for sleep disturbance effects. (Sonus, 2010)

Improvements in the design and implementation of control systems have greatly reduced sound emissions from wind turbines (see Figure 2). The top line gives the Sound Power Level increase with diameter for 1980s wind turbines and the bottom line gives the figure for 1990s wind turbines. Note this figure gives the total sound emitted from the turbine not the sound experienced by an observer.

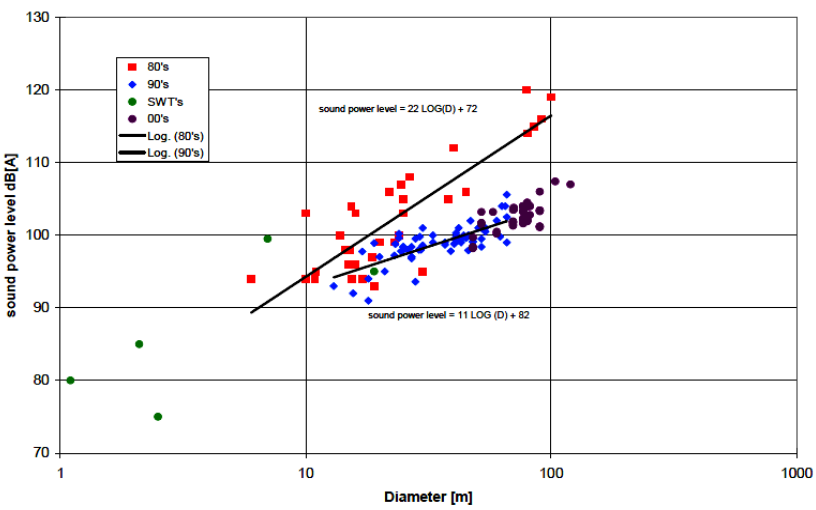

Figure 2: Sound power level values for wind turbines over three decades (Rogers et al, 2006)

Wind turbines generate three main types of sound which are discussed in the media regularly:

1. Infrasound <20 Hz
2. Low Frequency Sound 20 – 200Hz

3. Fluctuating aerodynamic “swish” from the turbine blades at low to moderate frequencies, approximately 250-1000 Hz. This is often described as amplitude or aerodynamic modulation.

Infrasound and low frequency sound

Due to complaints of low frequency and infrasound sound in the UK, the Department of Trade and Industry (DTI) commissioned acoustic consultants Hayes & McKenzie to investigate. Hayes and McKenzie took detailed measurements inside and outside houses, where complaints had been made, at three separate wind farms in Britain.

The report, published in 2006, found that *“infrasound emissions are significantly below the recognised threshold of perception for acoustic energy within this frequency range… Infrasound associated with modern wind turbines is not a source which will result in sound levels which may be injurious to the health effects of a wind farm neighbour.”*

Regarding low frequency sound, the report found that:

“The measurements performed at all three sites indicate that low frequency sound is measurable but below DEFRA (UK Department of Environment) Night-time Low Frequency Sound Criterion. However, wind turbine sound may result in internal sound levels which are just above the threshold of audibility as defined within [International Standards Organisation] 226. For a low frequency sensitive person, this may mean sound is audible within a dwelling. At all the measurement sites, low frequency sound associated with traffic movements has been found to be greater than that from the neighbouring wind farms and for one location, traffic sound was the sound which woke a sleeping resident.”

An expert panel review into “Wind Turbine Sound and Health Effects” for the American Wind Energy Association (AWEA) and Canadian Wind Energy Association (CanWEA) was conducted in 2009. This found *“there is a consensus among acoustic experts that the infrasound from wind turbines is of no consequence to health.”*

Aerodynamic Modulation (AM)

The 2006 DTI report did identify audible low frequency sound, which they called aerodynamic modulation. In this case the sound fluctuated in and out of audibility, for people with particularly sensitive hearing at low frequencies. As stated previously small changes in sound pressure level at low frequencies are perceived as large changes in sound. Therefore even a small amount of modulation (variation) in amplitude at low frequencies can be perceived more easily.

The cause of aerodynamic modulation is primarily the downward sweep of the blade tip. The study found that it may be the case that the modulation is more pronounced at night time when the atmosphere becomes more stable with a partial clear sky and light to moderate wind. In these conditions the near surface wind will be light, while the wind at hub heights of tall turbines will continue to be strong. This will reduce the masking effect of background wind sound.

To investigate these claims further the DTI and DEFRA commissioned a group of acoustics experts at Salford University.

The report investigated all 133 wind farms operating in the UK in December 2006, of which four were offshore. An email survey was sent to the appropriate local authority to determine any complaints filed.

This found that only 27 wind farms out of 133 had been subject to formal complaints. Specific information was collected for 19 of these sites totalling 206 complaints. However one wind farm had received 152 complaints, by removing this atypical figure the number of complaints at each site varied between 1 to 10, with an average of 3.

The questionnaire tried to classify the cause of the sound, based on the type of complaints and the Environmental Health Officers opinion. This found that AM was definitely in existence at 4 wind farms, with 8 others possible.

To determine the correlation between AM and complaints, the four sites for which AM was a cause of sound where further investigated.

At one site the complaints stopped after 1998 without any change to the turbines or wind conditions. This suggested the residents became more familiar with the sound and no longer considered it noise. At the second site where AM was a problem a control program was implemented to shut down three turbines when the winds came from an easterly direction. This reduced the complaints by 85% within two years.

For two sites where sufficient data existed it was determined that the meteorological conditions associated with AM occurred between 7% and 25% of the time.

The report's conclusion was that "considering the need for further research, the incidence of AM and the number of people affected is probably too small at present to make a compelling case for further research funding in preference to other types of sound which affect many more people."

The report also compared statistics from the UK Chartered Institute for Environmental Health from 2004/2005, which showed that the number of complaints about industrial sound was 7522 in a year and 286,872 for all sounds. This compared to around 14 per year for wind farms. Clearly sound from wind turbines is a much smaller problem than from other industrial sound sources.

Health Effects and Perception of Wind Turbine Sound

In July 2010 the Australian National Health and Medical Research Council released a "rapid review of the evidence" on "Wind Turbines and Health".

The evidence collected from peer reviewed research led to the conclusion that: *"there are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines".*

"Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effects in humans. Sub-audible, low frequency sounds and infrasound from wind turbines do not present a risk to human health."

It highlighted a number of studies which showed that the principle effects of wind turbine sound were not physiological but subjective.

W. David Colby, the Acting Officer of Medical Health at Chatham Kent Health Unit in Canada, and one of 7 experts involved in the AWEA and CanWEA 2009 review wrote in a 2009 letter to the Chatham Kent Council:

"In summary, there is no scientifically valid evidence that wind turbines are causing direct health effects … It is unlikely that evidence of adverse health effects will emerge in the future because there is no biologically plausible mechanism known by which wind turbines could cause health effects.

"An annoyance factor undoubtedly exists to which there is individual variability. Associated stress from annoyance, exacerbated by all the negative publicity, is the likely cause for the purported erosion of health that some people living near rural wind turbines are reporting. Stress has multiple causes and is additive."

A study by Pederson et al (2009) of sound response in the Netherlands, published in the Journal of the Acoustic Society of America, found a high correlation between the absence of economic benefits and opinion of visual impact and annoyance. This indicates that the perception of sound is potentially subjectively driven, rather than purely a negative aural response. This is shown in Figure 3.

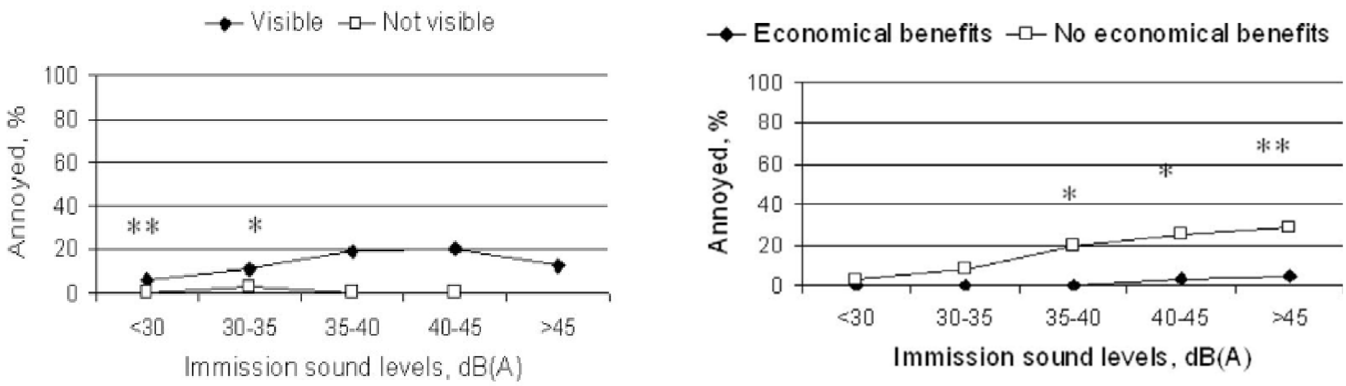

Figure 3: Correlation of annoyance and visibility of turbines and economic benefit (Pederson et al, 2009)

Claims that wind farms generate physiological health effects such as "vibroacoustic disease" (VAD) or "wind turbine syndrome" (WTS) have been refuted by numerous studies. The 2009 AWEA and CanWEA expert panel review, comprising 3 medical doctors and 4 acoustics experts, specifically criticised studies showing a link between wind farms and VAD or WTS for failing to conduct an epidemiological study that is needed to show a causal association. Instead all such studies, unpublished in peer reviewed journals, rely on "case studies", with self-selected cases being used to form an untested opinion. The expert panel review made it clear that only "case controlled" or "cohort" studies, where large sample sets are selected at random or in a controlled way to avoid biased results, are appropriate. As yet no such studies have been conducted into VAD or WTS.

As an alternative explanation for some of these reported health effects from wind farms, the idea of a "nocebo effect" has been advanced. A nocebo is a harmless substance or procedure which is perceived by the recipient to be harmful.

The 2009 AWEA and CanWEA study investigated the nocebo affect concluding that: *"the large volume of media coverage devoted to alleged adverse health effects of wind turbines understandably creates an anticipatory fear in some that they will experience adverse effects from wind turbines. Every person is suggestible to some degree. The resulting stress, fear, and hyper-vigilance may exacerbate or even create problems which would not otherwise exist. In this way, anti-wind farm activists may be creating with their publicity some of the problems that they describe."*

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