Wind Turbine Sounds – An Expert Panel Evaluation and Examples of Regulatory Approaches

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Expert Wind Turbine Sound Panel Evaluation

Health concerns have been raised by wind energy opponents noting that wind turbines emit dangerous levels of infrasound and low frequency sound which may result in vibroacosutic disease or wind turbine syndrome. Together the American and Canadian Wind Energy Associations (AWEA and CanWEA) proposed to a number of independent groups that they examine the scientific validity of reports on the adverse health effects of wind turbines. As no independent group or agency committed to conducting a review, AWEA and CanWEA commissioned a report in 2009. They asked a distinguished panel of independent experts in acoustics, audiology, medicine, and public health to examine published scientific literature on possible adverse health effects resulting from exposure to wind turbines.

The following independent experts were asked to investigate and analyze existing literature and publish their findings:

W. David Colby, M.D.**:** Chatham-Kent Medical Officer of Health (Acting); Associate Professor, Schulich School of Medicine & Dentistry, University of Western Ontario

Robert Dobie, M.D.**:** Clinical Professor, University of Texas, San Antonio; Clinical Professor, University of California, Davis

Geoff Leventhall, Ph.D**.:** Consultant in Noise Vibration and Acoustics, UK

David M. Lipscomb, Ph.D**.:** President, Correct Service, Inc.

Robert J. McCunney, M.D.**:** Research Scientist, Massachusetts Institute of Technology Department of Biological Engineering; Staff Physician, Massachusetts General Hospital Pulmonary Division; Harvard Medical School

Michael T. Seilo, Ph.D**.:** Professor of Audiology, Western Washington University

Bo Søndergaard, M.Sc. (Physics**):** Senior Consultant, Danish Electronics Light and Acoustics (DELTA)

Mark Bastasch, an acoustical engineer with the consulting firm of CH2M HILL, acted as technical advisor to the panel.

A series of conference calls were held among panel members to discuss literature and key health concerns that have been raised about wind turbines. The calls were followed by the development of a draft that was reviewed by other panel members. The study was completed and published in 2009, "Wind Turbine Sound and Health Effects: An Expert Panel Review" which is available at http://www.awea.org/learnabout/publications/loader.cfm?csModule=security/getfile&PageID=5728. What follows is a brief summary of the panel's findings.

The expert panel concluded that infrasound from wind turbines is not perceptible and does not exceed levels produced by natural sources. Low frequency sounds from wind turbines are not distinguishable from background sounds for frequencies less than 40 Hz, however, perceptible levels of low frequency sound may be produced under certain conditions. The audible swooshing sound is typically in the 500-1,000 Hz range; it is neither infrasound nor low frequency sound.

Dr. Nina Pierpont has hypothesized the existences of "Wind Turbine Syndrome" (WTS) based on telephone interviews with 10 families, who reported concerns with sleep disturbance, headaches, internal quivering, issues with concentration and memory, increased irritability and anger as well as issues with fatigue and motivation

Dr. Pierpont's hypothesis is that low levels of airborne infrasound affect the vestibular system or cause vibrations in internal organs (Visceral Vibratory Vestibular Disturbance – VVVD). The expert panel concluded that the proposed pathophysiological pathway is not plausible as low levels of sound from outside the body are not sufficient to exceed levels within the body and the vestibular organs respond to head position and movement, not airborne sounds emitted by wind turbines. The expert panel noted that "There are no unique symptoms or combinations of symptoms that would lead to a specific pattern of this hypothesized disorder". WTS symptoms are similar to those of noise annoyance. Potential for annoyance is not unique to wind turbines and depends on various acoustic and non-acoustic factors.

The expert panel unanimously endorsed the following conclusions:

- Sound from wind turbines does not pose a risk of hearing loss or any other direct adverse health effect.
- Subaudible, low frequency sound and infrasound from wind turbines do not present a risk to human health.
- Some people may be annoyed by the sound from wind turbines, but this is not a disease.
- A major cause of concern from wind turbine sound is its fluctuating nature. Some may find this sound annoying.

In May 2010, the Chief Medical Officer of Ontario, Canada reached similar conclusions to those of the independent expert panel:

- The scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects.
- Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur.
- Community engagement at the outset of planning for wind turbines is important and may alleviate health concerns about wind farms.
- Concerns about fairness and equity may also influence attitudes towards wind farms and allegations about effects on health. These factors deserve greater attention in future developments.

Varying Regulatory Approaches for Wind Turbine Sound

If not handled properly, concerns over sound may complicate both permitting and operations. To some it may be the "Soothing sound of money being made" while others may be quite disturbed by the change in their acoustical environment. As with other sources of environmental sound, the standards established for wind energy facilities by planning and permitting authorities vary in both their approach and quantitatively.

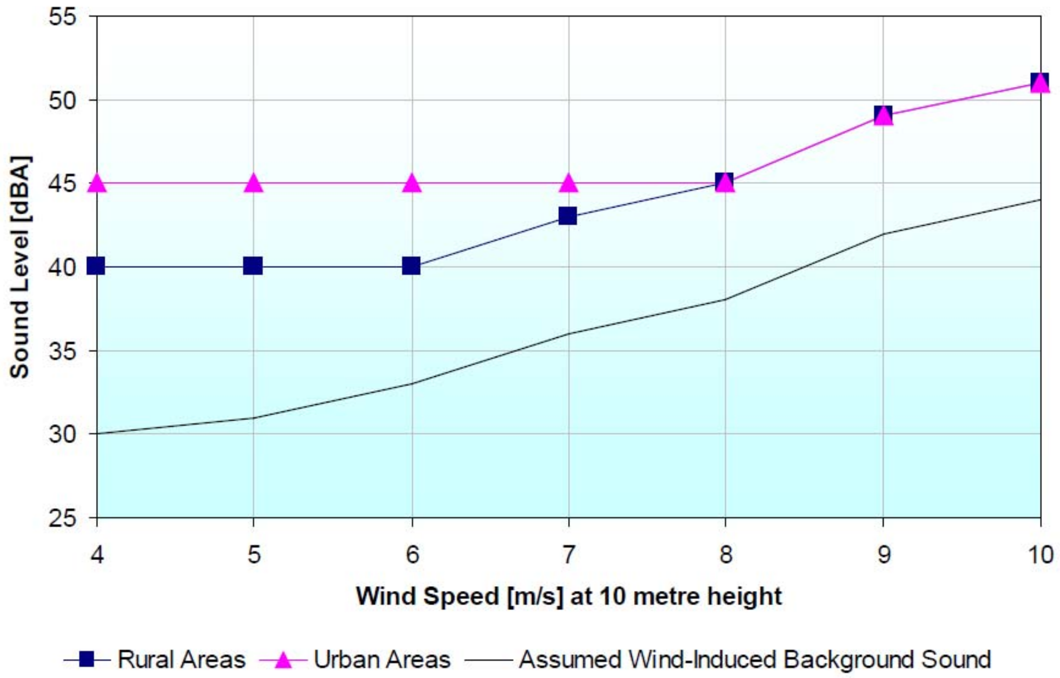
When comparing regulations between jurisdictions, the consistency with how that jurisdiction regulates other environmental noise sources is an important aspect to consider, as is population density and renewable energy policy. For example, the impact imposed by a 2 km residential setback requirement in Australia would have a less dramatic affect on the potential wind energy generating capacity than in smaller more densely populated areas such as the Netherlands or Japan. Overall, there are two distinct approaches: (1) establishment of absolute or fixed limits, or (2) relative limits which limit the increase over existing levels.

What follows are brief examples of the varying regulatory approaches. The reader is encouraged to confirm interpretation by reviewing permit conditions or consultation with relevant authorities.

Canada

The Ontario Ministry of the Environment (MOE) guidelines for the assessment of sound from wind turbines establishes relative limits with both a floor and ceiling (MOE, 2010). Rather than require monitoring to establish existing background levels, an assumed wind-induced background sound level is established. The standard also dictates the various modeling parameters to be used in ISO 9613. The standard essentially results in 40 dBA at residences in rural areas under moderate wind speeds (Figure 1).

FIGURE1. **Summary of Sound Level Limits for Wind Turbines in Ontario, Canada**



Source: MOE, 2010.

Netherlands

The regulations of wind turbine noise in the Netherlands were revised in 2010 (van den Berg, 2010). The previous regulations were similar to those discussed above for Ontario, Canada in that the residential noise limit was correlated with a 10-meter wind speed. The new Dutch limits are based on long term average sound power levels which are determined for each diurnal period (day, evening, night) from annual hub height wind speed statistics. The limits are expressed in terms of the preferred European Union metric, L_{den} (47 dBA) as well as L_{night} (41 dBA). As noted in van den Berg (2010) and references therein, the Dutch propagation model is similar to ISO 9613-2. In this method the propagation is calculated for downwind conditions, which are then adjusted to account for reductions afforded by periodic upwind conditions. The new requirements take into consideration the prevailing wind direction introducing a correction factor dependent on the angle under which the receiver sees the wind turbine. In addition, an additional correction may be made for directivity effects of the wind turbine itself (if such data is available). These meteorological adjustments range from 2.5 (residence predominately downwind) to 7.5 dBA (residence predominately upwind). As compliance measurements of a wind facilities long term average L_{den} are acknowledged to be problematic, the proposed method is to evaluate operational records and calculate the actual annual sound power distribution from which the receiver sound pressure level is predicted.   Measurements may be used to evaluate if the sound power of the turbine complies with the levels stated during permitting (i.e., verification of the turbine sound power levels).

The exterior L_{den} limit of 47 dBA was based on limiting the percentage of residents who are potentially highly annoyed indoors from wind turbine noise to 8%. The separate L_{night} limit of 41 dBA was established to address sleep disturbance. As discussed in van den Berg (2010) and references therein, a well developed dose-response relationship between wind turbine noise and sleep disturbance has not been established. The 41 dBA level was associated with 25% of respondents to a mail in survey noting that their sleep was disturbed at least once a month by sound, though the source of that sound was not identified. In setting the Lnight limit of 41 dBA the World Health Organization's 2009 Night Noise Guidelines for Europe were taken into consideration. The residents evaluated in determining these thresholds were those not benefiting financially from the wind facility; those benefiting from the wind facility were found to be much less or not annoyed or disturbed during sleep.

New Zealand

In 2010, New Zealand updated its standard for wind farm noise, New Zealand Standard 6808, Acoustics – Wind farm noise. The standard states that the wind farm sound level should not exceed the greater of 40 dB $L_{A90(10min)}$ or the existing background ($L_{A90(10min)}$) by more than 5 dB at noise sensitive locations (including residences). It is noted that a relative limit is appropriate as "it would not provided an acoustic benefit to restrict the wind farm sound levels to a fixed value on occasions when background sound levels (caused by wind) are higher than this value". Additional restrictions may be imposed on high amenity areas during the evening and nighttime hours, but these limits should not be less than 35 dB $L_{A90(10min).}$ The noise limits should apply to the cumulative sound level of all wind farms affecting the noise sensitive location. If the predicted levels of proposed new wind farm are at least 10 dB less than the existing wind farm, no cumulative effect is considered. Where predictions are employed, predicted Leq sound levels are taken as the L90 sound level for the purposes of assessing compliance with the above criteria. Potential penalties for special audible characteristics (for example, tonality, impulsiveness and amplitude modulation) are provided for and the sum of all penalties shall not exceed 6 dB. It is noted that additional restrictions addressing infrasound, low frequency noise or ground-borne vibrations are not justified.

Wind farm noise levels are predicted with ISO 9613 utilizing turbine sound power levels determined in accordance with IEC 61400-11. The standard establishes procedures for measuring and evaluating background and project sound levels. Hub height wind speeds are to be used in the evaluation of both existing background and project noise levels.

United States

The United States does not have a federal noise requirement for wind turbines and only a few states have industrial noise regulations. Therefore, the noise requirements of commercial-scale energy projects, including wind farms, may vary from one jurisdiction to another. The permitting process imposes noise requirements that vary from state to state. For example, large renewable and fossilfueled projects in Oregon require a permit from the State and undergo a detailed environmental review by the State. Other states, like California and Washington, do not require a state permit for wind energy projects; the local jurisdiction (city or county) is the lead permitting agency.

State of Washington

The State of Washington's general noise rules are applied to wind turbines. While local jurisdictions are allowed to develop independent, state-approved noise standards, it is primarily the urban communities such as Seattle that have done so. The State's noise limits are based on the environmental designation for noise abatement (EDNA), which is defined as "an area or zone (environment) within which maximum permissible noise levels are established." There are three EDNA designations that roughly correspond to residential, commercial/recreational, and industrial/agricultural uses.

Table 8.6 summarizes the maximum permissible levels applicable to noise received at noise-sensitive areas such as residences (Class A EDNA) and at industrial/agricultural areas (Class C EDNA) from a Class C EDNA.

TABLE 8.6
State of Washington Noise Regulations

	Maximum Permissible Noise Levels (dBA) from a Class C EDNA		
	Class A EDNA Receiver		**Class C EDNA Receiver**
Statistical Descriptor	**Daytime (7 a.m. – 10 p.m.)**	**Nighttime (10 p.m. – 7 a.m.)**	**Anytime**
L_{eq}	60	50	70
L_{25}	65	55	75
$L_{8.3}$	70	60	80
$L_{2.5}$	75	65	85

Source: Washington Administrative Code, Chapter 173-60.

State of Oregon

The Oregon noise regulations (Oregon Administrative Rule [OAR] Chapter 340 Division 35) contain two noise standards that are generally referred to as the "Table 8 test" and the "ambient degradation test" (other portions of the rules address octave, third-octave band and tonal limits). The "Table 8 test" refers to Table 8 of the rule (reproduced here as Table 8.7), which limits the maximum permissible statistical noise levels generated by a project. The "ambient degradation test" specifically limits the increase in the existing L10 or L50 to a maximum of 10 dBA.

TABLE 8.7
Oregon's Table 8 Limits": Maximum Permissible Levels for New Industrial and Commercial Noise Sources

Statistical Descriptor	**Daytime (7 a.m. – 10 p.m.) (dBA)**	**Nighttime (10 p.m. – 7 a.m.) (dBA)**
L_{50}	55	50
L_{10}	60	55
L_{1}	75	60

Source: Oregon Administrative Rule 340-35-035.

The rule allows an applicant to address the ambient degradation standard by accepting a minimum background L50 of 26 dBA, resulting in a noise floor of 36 dBA. The evaluation of these criteria is generally conducted with all turbines operating at their maximum warranted sound level consistent with the request by the State agency overseeing the permitting of large wind energy projects. The rule also exempts properties that have entered into a noise easement from the ambient degradation standard. For residences that have entered into a noise easement, the 50 dBA "Table 8" limit becomes the controlling limit.

Illinois

The Illinois Pollution Control Board (IPCB) noise regulations for industrial sources have been applied to wind turbines, although local jurisdictions may also develop their own standards. The IPCB regulations are specified in terms of receiving and source land use categories. The land use classifications generally correlate to residential (Class A), commercial/retail (Class B), and agricultural/industrial (Class C) land uses. All residences, even rural residences, are considered Class A. The most restrictive noise standard is generally determined by evaluating predicted levels at the residence against the criteria established for a Class C emitting source and a Class A receiving source as summarized in Table 8.8. Note that limits are established solely in octave bands and for wind turbine projects, the 500- or 1,000-Hz octave band tends to be the controlling limit.

TABLE 8.8
Illinois Noise Regulation – Sound Pressure Levels Emitted to Class A (Residential) from Class C (Industrial) (dB unweighted)

	Octave Band Center Frequency (OBCF - Hz)								
	31.5	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Daytime Limit (L_{eq}) (7:00 am to 10:00 pm)	75	74	69	64	58	52	47	43	40
Nighttime Limit (L_{eq}) (10:00 pm to 7:00 am)	69	67	62	54	47	41	36	32	32

Maine

The State of Maine Department of Environmental Protection noise regulations for "routine operation of developments" have been applied to wind turbines, although local jurisdictions may also develop their own standards provided they do not exceed the State regulations by more than 5 dBA. When projects are proposed in areas where the pre-development hourly L_{eq} is less than 45 dBA during the day or 35 dBA during the night, the resulting limit at protected residential locations is an hourly L_{eq} of 55 dBA during the day and 45 dBA during the night. Where existing levels are found to exceed the 45 dBA/35 dBA (day/night) the resulting limit is 60 dBA during the day and 50 dBA during the night. Penalties are assessed for both tonal and short duration repetitive sounds.

In September 2011, the Maine Board of Environmental Protection voted to impose more stringent noise regulations on commercial wind turbines operating near homes or businesses. This proposal included reducing the nighttime sound limit from 45 dBA to 42 dBA, provided additional detail on how compliance would be assessed and clarified how "short duration repetitive sounds" would be evaluated. As of October 2011, the State legislature had not adopted the Board's proposal.

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