CHARLES MIX COUNTY
STATES ATTORNEY
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August 22, 2018

South Dakota Public Utilities Commission
500 East Capital Ave.
Pierre, SD 57501

RE: APPLICATION BY PREVAILING WIN PARK, LLC FOR A PERMIT OF WIND ENERTY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA FOR THE PREVAILING WIND EL 18-026

Dear SDPUC Commission:

This letter is to follow up the phone conversation we had concerning Charles Mix County, SD, and Keith Mushitz's notice of intervening party and the STATE'S FIRST SET OF DATA REQUESTS TO CHARLES MIX COUNTY

As I stated during that phone conversation, Charles Mix County by and through its Commission Chairman, Keith Mushitz, sought to be an intervening party in the above entitled action. In hind sight, I am not sure that was necessary. Applicant has met with the Charles Mix County Commission concerning its project and the concerns of that board Charles Mix County is presently not zoned. In these meetings, the Applicant listened to the county's concerns about parameters of the project. In the end, Applicant agreed to build the project in Charles Mix County in a manner that reflects the Commission's wishes, i.e., Tower Setbacks, Tower Noise (DB level), Shadow Flickering, etc.. The Applicant signed an Affidavit and provided the Commission with that document which outlines these commitments. A copy of that Affidavit is attached hereto.

Given that, the County's request to intervene was only to provide the SDPUC with notice this agreement, to provide the SDPUC with the parameters of the agreement and to request that the SDPUC consider implementing Charles Mix County parameters in the final permit, if given, to the Applicant.

Thus, Charles Mix County does not plan to take depositions, testify or present witnesses during the application process of Applicant. In fact, Charles Mix County has no intention of attending any of the hearings unless called upon.

Thank you very much for your office's guidance in helping Charles Mix County better understand the Application process.

Sincerely,

Scott J. Podhradsky
Deputy State's Attorney
Charles Mix County

In the Matter of the Prevailing Wind Park Project in Charles Mix County, South Dakota

State of South Dakota)
) SS.
County of Charles Mix)

Affidavit of Peter Pawlowski

Peter C. Pawlowski, Vice President, Wind, Sustainable Power Group, LLC ("sPower") of the City of Salt Lake City, County of Salt Lake, State of Utah, being duly sworn on oath, deposes and states that the proposed Prevailing Wind Park will comply with the following requirements in Charles Mix County, South Dakota ("County"):

1. Prevailing Wind Park, LLC ("Prevailing Wind Park") is proposing to construct a wind energy system and associated facilities in Bon Homme, Charles Mix, Hutchinson and Yankton counties, South Dakota. As noted on its website, Basin Electric Power Cooperative has contracted to purchase the 200 megawatts of energy to be generated by the Project.[1] Up to 23 of the proposed turbines and associated facilities ("Project") would be located in Charles Mix County.

2. Prevailing Wind Park has been working cooperatively with the County to address questions regarding the Project.

3. Prevailing Wind Park is a wholly-owned subsidiary of sPower. In my position as Vice President, Wind, sPower, I am authorized to make commitments on behalf of Prevailing Wind Park.

4. Prevailing Wind Park hereby commits to the County Board of Commissioners that the Project will adhere to the following requirements:

   <u>Setbacks</u>.

   (a) Turbine tower distance from currently inhabited rural residence of a nonparticipating landowner shall be not less than three and a half (3.5) times the system height or two thousand feet (2,000) feet, whichever is greater. Turbine tower distance from the residence of the landowner on whose property the tower(s) are erected shall be not less than one thousand (1,000) feet.

   (b) Turbine tower distance from right-of-way of public roads shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater.

[1] https://www.basinelectric.com/About-Us/Organization/At-a-Glance/.

(c) Turbine tower distance from any property line shall be not less than five hundred (500) feet or one point one (1.1) times the system height, whichever is greater, unless a waiver has been obtained from adjoining property owner.

Noise. Noise from the wind turbines will not exceed 43 dBA at any existing nonparticipating residences and 45 dBA at existing participating residences, unless a signed waiver is obtained from the owner of the residence.

Shadow Flicker. Shadow flicker produced by the wind turbines will not exceed 30 hours per year and/or 30 minutes per day at currently inhabited residences of non-participants.

Lighting. The towers shall be lit using an Aircraft Detection Lighting System ("ADLS"), pending Federal Aviation Administration approval. The ADLS is designed to mitigate the impact of nighttime lights by deploying a radar-based system around a windfarm, turning lights on only when low-flying aircraft are detected nearby. The ADLS sends a signal to keep the light off until a plane is detected, then it stops sending the signal and the lights operate normally until the plane leaves the area and the off signal resumes.

Ice Detection. Prevailing Wind Park will use two methods to detect icing conditions on turbine blades: (1) sensors that will detect when blades become imbalanced or create vibration due to ice accumulation; and (2) meteorological data from on-site permanent meteorological towers, on-site anemometers, and other relevant meteorological sources that will be used to determine if ice accumulation is occurring. These control systems will either automatically shut down the turbine(s) in icing conditions (per the sensors) or Prevailing Wind Park will manually shut down turbine(s) if icing conditions are identified (using meteorological data). Turbines will not return to normal operation until the control systems no longer detect an imbalance or when weather conditions either remove icing on the blades or indicate icing is no longer a concern. Prevailing Wind Park will pay for any documented damage caused by ice thrown from a turbine

5. Prevailing Wind Park further commits to submitting this affidavit in the proceeding currently pending at the South Dakota Public Utilities Commission, *In the Matter of the Application by Prevailing Wind Park, LLC for a permit of a Wind Energy Facility in Bon Homme, Hutchinson and Charles Mix Counties*, Docket EL18-026.

Peter C. Pawlowski

Subscribed and sworn to before me
this 9th day of August, 2018

Notary Public
expires 4-19-2023

SEAL
SARA CLAYTON
Notary Public
SOUTH DAKOTA

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND PARK PROJECT	* * * * * * * *	**INTERVENORS' RESPONSES TO STAFF'S FIRST SET OF DATA REQUESTS TO INTERVENORS** **EL18-026**

Intervenors Gregg Hubner, Marsha Hubner, Paul Schoenfelder, and Lisa Schoenfelder ("Intervenors"), through counsel, provide the following Responses to PUC Staff's First Set of Data Requests to Intervenors.

1-1) Provide copies to Staff of all data requests served on Applicant at the time of service.

RESPONSE: This information will be provided.

1-2) Provide copies to Staff of all of your answers to data requests from Applicant at the time they are served on Applicant.

RESPONSE: This information will be provided.

1-3) Refer to SDCL 49-41B-22. Please specify particular aspect/s of the applicant's burden that the individuals granted party status intend to personally testify on.

RESPONSE: Intervenors are still evaluating the Application and Prevailing Wind Park LLC's ability to satisfy the provisions of SDCL 49-41B-22 and whether they will provide personal testimony on the same.

1-4) Refer to SDCL 49-41B-25. Identify any "terms, conditions, or modifications of the construction, operation, or maintenance" that the Intervenors would recommend the Commission order. Please provide support and explanation for any recommendations.

RESPONSE: Intervenors recommend a 2-mile setback from non-participating residences and a 1,500 ft. setback from a property line and public rights-of-way with waivers available for those who want them closer. Research shows the negative effects of wind turbines on people that live too close to turbines. In the book "Wind Turbine Syndrome" by Dr. Nina

Pierpont, MD, PhD, on page 254 she suggests a minimum of 2 mile setbacks. This book was written in 2009 when turbines were much smaller in megawatts and much shorter in size. There is no precedent for 586 ft. turbines. Attached as Exhibits 1-12 are various peer reviewed studies and articles on negative health effects. Intervenors are also concerned with ice-throws and malfunctioning turbines.

In Erik Johnson's public comments on the docket dated August 2, he says that 80% of the land in the footprint was signed up for the project. If that is the case, then a 2-mile setback for non-participants would be very easy to accommodate. If the Applicant has 80% of the land signed up, all it must do to make this work is move a few turbine locations.

Intervenors request the Aircraft Detection Lighting System which eliminates the red blinking lights at night.

Intervenors request a decommissioning bond paid for in its entirety prior to construction.

Intervenors request a liaison person or watchdog to monitor the project as it is being built to ensure compliance.

Intervenors request there should be no shadow flicker on non-participating residences, because shadow flicker presents a nuisance and the Applicant should not be permitted to create a nuisance.

1-5) Is there a specific objection (example health, blinking lights, sound) you have with respect to the Project? Please briefly explain.

RESPONSE: Intervenors are still evaluating the Application and their objections thereto. Presently, though, Intervenors are concerned with the sound, infrasound, and shadow flicker that will be created by the proposed turbines. The effects of infrasound are serious and documented. Studies show 35 decibels or less results in very few complaints. See also response to Data Request 1-4.

a. What, if anything, do you feel could be done to remedy that issue?

RESPONSE: 2-mile setbacks from non-participating residences and 1,500 ft. setbacks from a property line and rights-of-way (with waivers) and 35 decibel noise limit for non-participating residences.

1-6) Please list with specificity the witnesses the Intervenors intend to call. Please include name, address, phone number, credentials and area of expertise.

RESPONSE: Intervenors are still evaluating the Application and considering potential witnesses.

1-7) Do the you intend to take depositions? If so, of whom?

RESPONSE: Not at this time.

Dated this 30th day of August, 2018.

DAVENPORT, EVANS, HURWITZ & SMITH, L.L.P.

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CERTIFICATE OF SERVICE

The undersigned, one of the attorneys for Intervenors Gregg C. Hubner, Marsha Hubner, Paul M. Schoenfelder and Lisa A. Schoenfelder, certifies that a true and correct copy of Intervenors' Responses to Staff's First Set of Data Requests to Intervenors was served on August 30, 2018, via email, upon the following:

Ms. Kristen Edwards
kristen.edwards@state.sd.us
Ms. Amanda Reiss
Amanda.Reiss@state.sd.us
Staff Attorneys
South Dakota Public Utilities Commission
500 E. Capitol Ave.
Pierre, SD 57501

Dated this 30th day of August, 2018.

Reece M. Almond
One of the Attorneys for Intervenors

The Noise From Wind Turbines: Potential Adverse Impacts on Children's Well-Being

Arline L. Bronzaft
Bulletin of Science Technology & Society 2011 31: 291
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Intervenors' Responses to
Staff's First Set of Data Requests
EXHIBIT 1

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The Noise From Wind Turbines: Potential Adverse Impacts on Children's Well-Being

Arline L. Bronzaft[1]

Abstract

Research linking loud sounds to hearing loss in youngsters is now widespread, resulting in the issuance of warnings to protect children's hearing. However, studies attesting to the adverse effects of intrusive sounds and noise on children's overall mental and physical health and well-being have not received similar attention. This, despite the fact that many studies have demonstrated that intrusive noises such as those from passing road traffic, nearby rail systems, and overhead aircraft can adversely affect children's cardiovascular system, memory, language development, and learning acquisition. While some schools in the United States have received funds to abate intrusive aircraft noise, for example, many schools still expose children to noises from passing traffic and overhead aircraft. Discussion focuses on the harmful effects of noise on children, what has to be done to remedy the situation, and the need for action to lessen the impacts of noise from all sources. Furthermore, based on our knowledge of the harmful effects of noise on children's health and the growing body of evidence to suggest the potential harmful effects of industrial wind turbine noise, it is strongly urged that further studies be conducted on the impacts of industrial wind turbines on their health, as well as the health of their parents, before forging ahead in siting industrial wind turbines.

Keywords

health, cognition, language, learning, wind turbines, transportation, well-being

Introduction

Thirty-six years ago, when my then 8-year-old daughter learned I was looking at the impact of passing train noise on children's classroom learning, she asked me why I was conducting this study because it seemed obvious to her that passing train noise disrupting children's learning every 4 to 5 minutes for 30 seconds would affect their learning ability. I responded that someone had to demonstrate the impact of the noise on classroom learning with solid data, explaining the meaning of data to my daughter.

Assessing the Impacts of Noise on Children's Learning

My initial study on noise/learning link examined the impact of elevated train noise on reading ability in a school situated 220 feet from an adjacent elevated train structure. Eighty trains passed the school during the hours between 9 a.m. and 3 p.m. each weekday and disrupted the classes on the side of the building facing the tract every 4½ minutes for 30 seconds. The sound level in a classroom rose to 89 dBA from 59 dBA when the train passed, forcing the teacher to scream to be heard or to stop teaching until the train passed. In 1973, the New York Department of Air Resources reported that 11% of classroom teaching time was lost because of passing trains.

Reading scores were examined for 4 years comparing the scores of the children in the classrooms exposed to train noise with children attending classrooms on the quiet side of the building. Reading scores of children on the noisy side of the building lagged behind their peers on the quiet side from 3 months in the lower grades to as much as 1 year in the sixth grade. Whether the cause was the lost teaching time, the distraction of the trains, or the fact that the children took the tests in the noisy rooms, the fact remains that children in the noisy classrooms demonstrated poorer reading scores than children on the quiet side of the building. My results were published in a article in 1975 in the *Journal of Environment and Behavior* (Bronzaft & McCarthy, 1975).

Responding to Effects of Noise on Learning

The reaction to this study in New York City was overwhelming. Newspaper accounts of the study plus statements by public officials highlighted the findings broadly. This reaction made

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it easier for me to approach the Transit Authority and ask the agency to select the tracks adjacent to P.S. 98 to test the effectiveness of rubber padding in quieting noisy elevated trains. When the pads were in place, the principal of the school and I asked the Board of Education to install noise abatement materials in three of the noisiest classrooms at P.S. 98. The noise reduction as a result of the two abatement techniques was 6 to 8 dBA. When asked to return to the school by a public official to conduct a study after the installation of noise abatement materials, I did so nervously. However, when I compared the reading scores of children in classrooms facing the tracks with those on the quiet side of the building, children on both sides of the building were reading at comparable levels. This study clearly demonstrated that when you correct a noise problem, children benefit (Bronzaft, 1981).

Research on Effects of Noise on Children's Learning Expands

Subsequent years saw additional research on the effects of noise on children's learning. Wachs and Gruen (1982) noted that noisy households can disrupt a child's development and warned parents about shouting and playing televisions and stereo systems too loudly. The U.S. Federal Interagency Committee on Aviation Noise (FICAN) concluded, after summarizing the findings of 20 studies, including my study in 1975, that aircraft noise can interfere with reading, speech acquisition, and noise (FICAN, 2000). Lercher, Evans, and Meis (2003) examined ambient neighborhood noises and found that chronic noise exposure was significantly related to poor incidental and intentional memory in children. S. A. Stansfeld et al. (2005) reported that an investigation of school children in the Netherlands, Spain, and the United Kingdom indicated that aircraft noise could impair cognitive development, especially reading comprehension. Recent studies by Matheson et al. (2010) and S. Stansfeld, Hygge, Clark, and Tamuno (2010) add to our knowledge of the adverse effects of road traffic and aircraft noise exposure on children's learning abilities, particularly in the school setting.

In my book *Top of the Class*, published in 1996, which examined the lives of high academic achievers, I learned from these high academic achievers that they were reared in homes that respected quiet (Bronzaft, 1996). Quiet areas were provided for them to read, study, and learn. Their parents tended not to discipline them with shouting and loud voices but rather used lowered, stern voices to correct their behavior. We could say that a quieter environment served these high academic achievers well.

Greater Awareness of Noise/Learning Link?

U.S. President Obama understands that noise can affect classroom learning. In a speech before Congress in February 2009, the President identified a young woman in the audience named Ty'Sheoma Bethea who attended a school in Dillon, South Carolina. In identifying the elements impeding on the learning in her classroom, he noted that "they have to stop teaching six times a day because the train barrels by their classroom." The American National Standards Institute in 2002 set acoustical standards for classrooms, stressing the importance of a proper acoustical school environment. In 2009, the House Education and Labor Committee of the U.S. Congress passed a bill that would introduce measures designed to reduce or eliminate exposure to classroom noise, as part of the Green High Performing School Facilities Act, but this legislation has not yet become law.

My daughter, now 44 years old, wonders why after years of research demonstrating a link between noise and children's learning, we need to conduct further research as suggested by the U.S. Federal Aviation Administration's (FAA) proposed study on the effects of aircraft noise on classroom learning (Airport Cooperation Research Program, Project Number 02-26). She believes there is enough research demonstrating an adverse effect of noise on learning and we should move, without hesitation, to creating quieter classroom environments rather than using funds to conduct further studies. Despite the fact that I serve on the Transportation Research Board committee that is overseeing the FAA-funded research on airport noise and children's schoolroom learning, I tend to agree with my daughter's conclusion. In 2011, there definitely is sufficient research linking noise to impaired learning and we should work toward improving the school learning environment.

Impacts on Children Beyond Learning

It should be pointed out even if the child were able to overcome the adverse effect of noise in the classroom, the need to do so may create stress and discomfort for the child, which in the long run can have an adverse effects on his or her health. In my 1974 study, the children interviewed expressed their unhappiness at the passing trains. One child, when interviewed for television, said, "I wish the trains wouldn't run anymore."

Noise has been associated with physiological problems in children. Studies on the adverse effects of loud sounds and noise on children's hearing have been well documented. Yet youngsters continue to expose themselves to loud video games, loud concerts, and so on. An example of the effects of long-term exposure to loud music is Pete Townshead, a member of the rock band "The Who," who has experienced hearing problems himself because of his exposure. Yet hearing loss is not the only physiological impact of noise. Evans and Lapore (1993) reviewed the nonauditory effects of noise and concluded that children living near or attending a school near a major airport were more likely to experience elevated blood pressure. Passchier-Vermeer and Passchier (2000) wrote that road traffic and aircraft noise have been found to affect children's cardiovascular system. The U.S. government over

30 years ago in its "Noise: A Health Problem" pamphlet stated that children in homes and schools exposed to aircraft noise had higher blood pressure than children in quieter environments (U.S. Environmental Protection Agency, 1978). Although this booklet pointed out back then that more studies were needed to strengthen this finding, it concluded with the statement that "this finding is cause for concern."

When Parents Are Stressed, Children May Suffer!

Another point that I would like to make concerning the impacts of noise on children's lives deals with the effects noise has on their parents. There are sufficient studies linking noise to adverse health effects (Bronzaft & Hagler, 2010) in adults. Even if we were to argue that the best data linking noise to well-being centers on a diminished quality of life rather than specific health ailments, as noted by the World Health Organization, then living near a noisy source would most likely diminish quality of life. Good health is not merely the absence of symptoms; it is the ability to experience a decent quality of life. Parents experiencing this poorer quality of life, or suffering from a noise-related ailment, may have less patience with their children and, as a result, express more anger at their misdeeds. I need not illustrate further how good parent-children relationships affect the health and well-being of children. If noise prevents a parent from getting a good night's sleep because of overhead aircraft, then one could expect this tired parent to be less able to deal with the obligations of parenthood.

Going Beyond Existing Findings on Noise Impacts

How does my discussion of the impacts of noise, largely measured on the dbA scale, on children's mental and physical health relate to the topic of wind turbine noise, including sound levels measured on the A scale as well as potential impacts from low-frequency sound. What I think we can learn from the research on the effects of noise on children is that before changes are made based on research findings, authorities demand solid data with huge samples. Occasionally, there are exceptions, as I experienced in the case of the New York Transit Authority and the New York City Board of Education actions to abate the noise at the school in which I had conducted my research on noise and learning. Although studies such as mine did influence the U.S. FAA to abate noise at schools lying within a designated noise area, it is difficult for schools to receive this abatement, largely because the noise metrics used by the FAA limit the numbers of schools that may be eligible. Thus, far too little has been done in the United States to lessen the effects of intruding noises from traffic, trains, and aircraft, despite a growing body of literature linking noise to adverse impacts on children's mental and physical health. With respect to wind turbine noise, the solid data we now have regarding the noise/health link in children should serve to warn about the potential harm of wind turbine noise and caution should be exerted before building industrial wind turbines near people's homes.

How Valid Are the Data in Support of Wind Turbines?

Before the academically reviewed journal articles are written and published, researchers explore problems employing observations and interviews. Before I conducted my research as noted above, parents of the children at P.S. 98 had long complained about the noise from the trains but no action was taken until after the findings of my research were published. However, I want to add that many public officials in New York City joined in our efforts to quiet the tracks next to the school and that hastened the abatement. Similarly, Dr. Pierpont (2009) was responding to resident complaints when she undertook her observations and interviews of residents living with wind turbine noise. Dr. Pierpont's observations, and those of other speakers who presented at the recent First International Symposium on the Global Wind Industry and Adverse Health Effects held in Ontario, Canada, are being questioned because they appear to be based on small numbers of residents. The validity and reliability of these observations are also being criticized because they lack comparisons with control groups. In the early days of psychology, Dr. Freud took careful notes on his patients' complaints and he relied on observations and interviews as he formulated his theory of human behavior. In time Dr. Freud, one of the great minds of the 20th century, developed a theory of human behavior, as well as a method to treat psychological problems. More traditional studies of his theories followed afterwards. Observations and interviews generally proceed questionnaires and testing that result in correlative data to be analyzed and evaluated.

The dismissal of the adverse effects of noise on residents living with wind turbine noise has largely come from the wind power industry, which has supported this claim with reports by acousticians, doctors, and engineers whom they have hired to write on the noise/health relationship. Yet there exist reports written by researchers that suggest that both the wind industry and governments in favor of wind turbine energy have erred in concluding that noise from wind turbines cannot affect physical and mental well-being. Dr. Frits van den Berg (2004), a Dutch physicist, claims that the methods used to predict the noise from large turbines are inappropriate and, thus, the conclusions drawn from findings based on these methods have to be questioned. Dr. van den Berg believes that the measurements of wind turbine noise near people's homes in quieter environments at night may be underestimated by as many as 10 dBA. Dr. van den Berg's conclusions have been supported earlier by Pedersen and Halmstad (2003). Studies such as these deserve to be examined more closely and, at the very least, suggest that additional studies be conducted to evaluate the impacts of wind turbine noise, including the low-frequency sounds, on individuals.

A Growing Interest in the Impacts of Wind Turbine Noise

Garret Keizer in his book *The Unwanted Sound of Everything We Want* (2010) states that while he is not an expert on wind turbine noise, he can still write as an individual who personally researched the issue of noise and wind power, including the works of van den Berg and Pedersen, for his book. He also personally visited residents in Maine who described how the wind turbine noise affected their lives. Mr. Keizer concluded that "wind turbines produce a devilishly complex form of noise that, combined with the imprudent siting of certain wind installations, is making some people sick." (p.221) Additionally, Mr. Keiser, in thinking about future environmental debates, states that "in debates over wind energy, noise will be front and center." (p.221)

In a *New York Times* article (Zeller, 2010), Mr. Zeller gives voice to residents who have had their quality of life diminished by nearby wind turbines, but then adds that "for the most extreme claims, there is little independent backing." Unfortunately, the only studies he cites are those from American Wind Energy Association, a trade group, and its Canadian counterpart, which concluded that "there is no evidence that the audible and sub-audible sounds emitted by wind turbines have a direct adverse physiological effects." The *New York Times* published two additional articles shortly afterwards (Wald, 2010; Wald & Zeller, 2010) on wind power energy. Additionally, President Barack Obama mentioned wind power as an alternative energy source that we must pursue in his State of the Union address in early January 2011. That Mr. Keizer's noise book, and the soon to be published book *Why Noise Matters* (Stewart, 2011), contain sections on wind turbine noise and that several stories on wind power have recently appeared in the *New York Times* indicate a both a growing interest in wind power as an alternative energy source as well as a source for potential harm from noise.

A Call for More Research

Yet this interest in harnessing wind power must be accompanied by research to resolve the issues of the potential harm of wind turbine noise on individuals living nearby. Research should also be conducted on the cost-effectiveness of harnessing the wind among other concerns. From past experience, I would venture to guess that the eagerness to move to wind power on the part of industry and governments internationally will result in a reluctance to support research that may conclude that caution is required when locating wind turbines close to residential communities. Of course, I speak from an American perspective where history has demonstrated how quickly Americans adopt new products, without requisite research on harmful effects, and how reluctantly they relinquish these products when evidence proves that they may be harmful. Similarly, when it comes to environmental concerns, the United States often errs on the side of industry, as noted by a *New York Times* editorial ("Questions About Fracturing," 2010), and proceeds with activities that might be harmful to the environment. In this editorial, the concern is hydraulic fracturing, which has been implicated in a number of water pollution cases. The drilling industry, like the wind power industry, states that its technology is "fundamentally sound" but the editorial adds: "We need more credible assurances this time." Yet the United States is most likely not alone in requiring *overwhelming* evidence to remove dangerous products or to proceed with dangerous technology.

Enough Evidence to Issue Warnings About the Hazards of Wind Turbine Noise

The U.S. Environmental Protection Agency released a booklet in 1978 that contained a section entitled "Special Effects on Children" and cited my research on the impacts of noise on children's classroom learning. The booklet in its final word section concludes: "It is finally clear that noise is a significant hazard to public health. Truly, noise is more than an annoyance." In 2009, the U.S. Environmental Protection Agency (http://www.epa.gov/air/noise.html) issued a pamphlet entitled "Say What" for middle school students, which states, "Noise can not only harm your hearing—it can also make it hard to concentrate while reading or doing homework, make you frustrated, prevent you from falling asleep, and make it hard to communicate with your family and friends."

Yet, despite declarative statements in government publications, and I could have added others to those cited above, the U.S. government is still assessing the impact of aircraft noise on children's learning and still thinking about passing legislation to quiet the nation's schools. With the American educational system falling behind the systems of other nations, especially evidenced in the lower number of people graduating from college, it is indeed egregious to allow our school children's education to be adversely affected by noise both inside and outside the school as well as the home. It would also be egregious to fail to consider the impacts of new sources of noise, for example, industrial wind turbines on their health.

Dr. William H. Stewart, the former Surgeon General of the United States, in a keynote talk to a 1969 Conference on Noise as a Public Health Hazard stated the following: "Must we wait until we prove every link in the chain of causation. In protecting health, absolute proof comes late. To wait for it is to invite disaster or to prolong suffering unnecessarily." I was taught that an ounce of prevention was worth more than a pound of cure. I believe we should explore the potential harmful noise effects of industrial wind turbines before we adopt this energy source; taking corrective action many years down the road, when the proof is overwhelming, would be, as Dr. Stewart says, "prolonging suffering unnecessarily."

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Bio

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Wind Turbine Noise

John P. Harrison

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Wind Turbine Noise

John P. Harrison[1]

Abstract

Following an introduction to noise and noise regulation of wind turbines, the problem of adverse health effects of turbine noise is discussed. This is attributed to the characteristics of turbine noise and deficiencies in the regulation of this noise. Both onshore and offshore wind farms are discussed.

Keywords

wind turbines, turbine noise, onshore and offshore noise propagation, noise regulation, turbulence

Introduction

The most common complaint about wind turbines is that they are noisy. There is audible noise perceived by the ear/brain system and the so-called inaudible infrasound felt by the body. The ear detects sound as pressure waves. The ear/brain system detects the loudness and pitch of the sound. The way the system works is that as the pressure in a sound wave increases by three times, the ear/brain combination perceives a doubling of the loudness. The ear/brain system for audible sound is effective from about 50 to 4,000 Hz with a gradual decrease in sensitivity at either end.

Engineers use a decibel scale to describe loudness as perceived. The scale is logarithmic to mimic the behavior of the ear. The scale is weighted to reflect the sensitivity of the ear to the frequency of the sound. The most common weighting is the A-scale. With this scale, familiar noises have approximate decibel levels as shown.

Background at night in a rural area:	25 dBA
Recommended bedroom level:	25 dBA
Living room:	40-45 dBA
A busy office:	60-65 dBA
Heavy street traffic:	90 dBA

An increase of 3 dBA is noticeable and an increase of 10 dBA is perceived as a doubling in loudness. Sound from extraneous sources is referred to as noise and is an annoyance and potential health problem.

The response to infrasound (<20 Hz) is not as well understood. However, there are receptors in the body for infrasound and it is detected at levels well below the audible sound threshold (Salt & Hullar, 2010).

Most noise regulations are derived from regulations designed for other noise sources, such as traffic or industry. However, anecdotal evidence and field studies suggest that turbine noise has a character that makes it far more annoying and stressful than other sources of noise at the same A-weighted sound level. The reasons for this are believed to include the amplitude modulation associated with the blade passage past the tower, the quiet rural environment in which turbines are placed, the turbulence of the air that blows past the blades, the variability of manufacture and assembly, the dominance of low frequencies in the received sound spectrum, and the association between the acoustic and visual impacts. This article reviews the annoyance and its impacts, the character of the turbine noise, and suggests revisions to regulations required to avoid adverse health effects.

Regulation of Wind Turbine Noise

Most jurisdictions have noise regulations to protect our environment from industrial, traffic, and other sources of noise. Regulation of wind turbine noise is used to determine the setback of turbines from homes and other sensitive receptors. For a review of regulations worldwide, see Orville Walsh (2010). The noise limit varies from 35 dBA for quiet regions of New Zealand and for nighttime in Germany to 50 dBA in many jurisdictions in the United States.

In Ontario, there is an Environmental Protection Act, which, among other thing, protects the health and the enjoyment of property of residents. As of September 2009, the limit for turbine noise at a sensitive receptor is 40 dBA. There is in addition a minimum setback of 550 meters from sensitive receptors. Typically, the ambient nighttime noise in a rural area is 25 dBA. The 15 dBA intrusion of the turbine noise above

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ambient corresponds to a sound three times as loud as the ambient, well above the 3 dBA detectability.

Ontario is now unique in allowing the noise limit to rise with the wind speed, up to 51 dBA at a wind speed of 10 m/s. The justification is based on masking noise from the wind. This is discussed further below.

Significance of Turbine Noise Regulation

It is usual when planning a wind farm to base the setback of the turbines from homes on the local noise regulation. Of course, there are many wind farms in unpopulated regions and noise is not a concern. However, in many cases turbines are being "shoe-horned" (Rolf Miller, Director of Wind Assessment at Chicago-based Acciona Windpower, quoted in Del Franco, 2011) in and noise is the dominant concern. The protocol is to base the siting of turbines on the prediction of the noise at a receptor. There is no routine testing for compliance postconstruction and therefore no feedback on the planning of future wind farms. In cases where complaints have led to noise audits that have demonstrated noncompliance, the receptors have been compensated but still no feedback.

There is routine software that starts with the coordinates of the proposed turbine sites and the turbine noise specifications and outputs noise contours for the area of the wind farm. The contour maps are drawn for a range of wind speeds. The noise specification is the sound power, with the total sound power from the extended source (the blades and nacelle) treated as a spherical source of area 1 m^2, as a function of the wind speed and sound frequency. The software uses a sound propagation algorithm such as ISO 9613-2. In turn, this algorithm requires a ground effect parameter and an atmospheric absorption parameter. The algorithm basically accounts for spherical spreading of the sound wave from the source, reflection and absorption by the ground, and frequency-dependent absorption by the atmosphere.

A typical result, expressed as sound pressure level in dBA as a function of distance of the turbine from a receptor, is shown in Figure 1. A turbine sound power level of 105 dBA was chosen for the example. The lower curve corresponds to a single turbine and the upper curve to 3 turbines equidistant from the receptor. Highlighted on the figure are regulated noise limits of 35 and 40 dBA.It is seen that a 40 dBA noise limit, calculated in this way, corresponds to a setback of about 500 meters. Rarely is a receptor overlooked by a single turbine. For three equidistant turbines, the 40 dBA limit corresponds to a setback of 800 meters. Seen in this light, it is clear that the 550 meters minimum setback specified by the Ontario Ministry of the Environment as part of the Green Energy Act turbine noise regulation is meaningless.

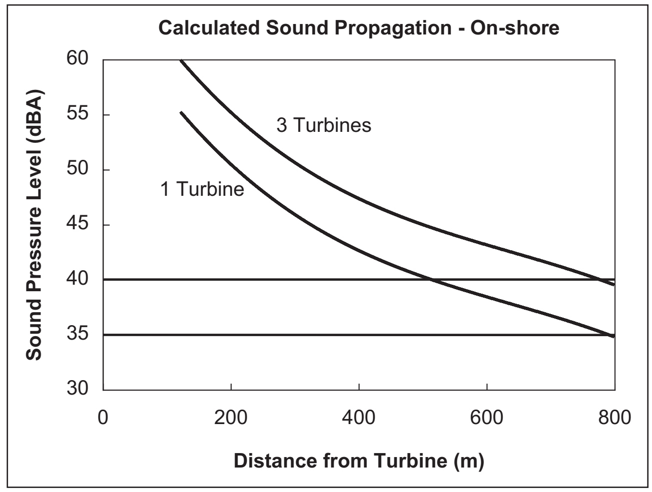

Figure 1. Predicted sound pressure level versus distance from turbine

Noise and Adverse Health Effects

Turbine noise causes annoyance, sleep disturbance and deprivation, and can result in adverse health effects (see, e.g., Frey & Hadden, 2007; Harry, 2007; McMurtry, 2009; Pierpont, 2010). On the basis of the study of widespread complaints of adverse health effects due to turbine noise, various health authorities have recommended setbacks in the range 1.5 to 2 kilometers from homes and other sensitive receptors. In addition to the "one on one" interactions between health professionals and complainants, there have been field studies of the annoyance caused by turbine noise. Perhaps the most significant are the Netherlands study recently reported by Pedersen, van den Berg, Bakker, and Bouma (2009) and the earlier Swedish studies reported by Pedersen and Persson Waye (2004, 2007); the significance is based on the size of the samples, the experience of the investigators and the intercomparison between the studies.

The results are summarized in Tables 1 and 2. The authors used five categories for the response to turbine noise of those survey respondents: did not notice, noticed but not annoyed, slightly annoyed, rather annoyed, and very annoyed. The sound level at the respondents' homes was calculated using ISO 9613-2. The resulting sound levels were checked against two other algorithms with no significant difference found (<1 dBA). A ground absorption parameter of 1 (perfectly absorbing) was used in the ISO calculation. This is the same value as used by Ontario, for instance.

It would appear that a noise limit of 40 dBA will result in annoyance (rather plus very annoyed) for about 20% of the population subject to that noise level. Again, for many wind farms in low-populated regions this is not a problem because there is no need to site to the noise limit. However, where rural populations are denser and where turbines are being "shoe-horned" in, this is a problem. Southern Ontario, Quebec,

Table 1. Respondents in Rural Sweden (N = 1095)

Noise (dBA)	Rather Annoyed (%)	Very Annoyed (%)	Total (%)
35-40	3	6	9
40-45	10	19	29

Table 2. Respondents in Rural Netherlands (N = 586)

Noise (dBA)	Rather Annoyed (%)	Very Annoyed (%)	Total (%)
35-40	14	6	20
40-45	7	18	25

Nova Scotia, and Prince Edward Island are obvious examples from Canada.

For comparison, it is interesting to note that Miedema and Vos (1998) found that just 2% to 4% of respondents were annoyed by traffic noise at the 40 dBA level.

Reconciliation Between Regulation and Adverse Health Effects

There is a problem. Noise regulation in the range 40 to 50 dBA allows turbines to be placed within 500 meters of homes and other sensitive receptors. Subsequently, in a significant fraction of such homes, residents are being annoyed, are suffering sleep deprivation and disturbance, and in many cases, are suffering adverse health effects. Yet for other noise sources the limit appears reasonable. We now know that turbine noise has characteristics that contribute to this situation. We also know that there are factors not considered when applying the noise regulations. Finally, there is a reluctance to test for compliance. One can understand the reluctance; each turbine costs about $5 million to put in place and unlike industrial machinery there is no possibility of shielding the noise at source. Nevertheless, regulation without compliance testing is unethical.

The characteristics of turbine noise that contribute to annoyance and sleep disturbance are as follows: The sound from turbines is amplitude modulated at the blade passage frequency. The modulation level is typically 3 to 5 dBA (van den Berg, 2005) but higher levels have been measured (Moorhouse, Hayes, von Hünerbein, Piper, & Adams, 2007). Two things arise: The peak sound is higher than the average used for noise regulation and the modulation enhances the audibility of the sound to such an extent that the turbine noise can be detected even when the sound is below ambient (Hanning, 2010). The noise emitted by a turbine is broadband; however, at a distance of 500 meters and more, the higher frequencies have been absorbed by the atmosphere so that it is predominantly low-frequency noise that reaches a receptor. This low-frequency noise enhances annoyance and is more readily able to penetrate walls and resonate inside rooms. Many people report a thumping, rumbling, or impulsive character to the turbine noise (e.g., Frey & Hadden, 2007; Harry, 2007); the reason is not clear.

Deficiencies With Present Noise Regulation

As noted above, the character of turbine noise makes it especially intrusive. This is exacerbated by the fact that wind turbines are sited in rural areas where the ambient noise level can be about 25 dBA. An intrusion of 15 dBA is too large. Germany has a nighttime noise limit of 35 dBA; this should be the international absolute maximum.

Also as noted above, the standard algorithm for predicting noise at a receptor is ISO-9613-2. But, this was never designed for turbine noise. The ISO manual is specific in limiting its use to noise sources close to the ground such as "road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources." Turbine noise derives from blades rotating, typically, between 35 to 125 meters above ground level. When used without compliance, testing the results of the predictions have little meaning.

The authors of noise prediction algorithms appreciate that there is uncertainty in the calculations. For instance, the manual for ISO 9613-2 puts the uncertainty at ±3 dBA for a source to receptor distance in the range 100 to 1,000 meters. The turbine makers know that there is variability in manufacture; this is put at ±1 or ±2 dBA. Combining these, the predictions can be no better than ±4 dBA. This uncertainty is ignored by the wind energy developers and by the regulatory authorities. This is despite the fact that the final siting plans are signed off by professional engineers and approved by professional engineers.

All prediction algorithms assume spherical spreading of the sound from the turbines. This is not necessarily always so. Sound propagation experiments over hard surface, such as water or packed sand, have demonstrated a transition from spherical to cylindrical spreading even for distances of less than 1 kilometer (Boué 2007; Hubbard & Shepherd, 1991). Packed snow would be another example of a hard surface. The cylindrical spreading is a result of refraction of sound in the atmosphere and channeling of sound between the atmosphere and the ground (Søndergaard & Plovsing, 2005).The distance at which the transition occurs depends on the wind speed and temperature gradients in the low atmosphere and will vary with time of year, time of day, and weather.

Turbines leave behind them a turbulent wake and a wind speed deficit. Turbulence is known to exacerbate turbine noise (Amiet, 1975; Moriarty, 2004; Moriarty, Guidati, & Migliore, 2004, 2005; Moriarty & Migliore, 2003; Romera-Sanz & Matesanz, 2008). Turbulence occurs naturally in the atmosphere but the wake turbulence can equal this natural turbulence out to 5 blade diameters (Barthelmie et al., 2003). Experiments with an isolated turbine at the National Renewable Energy Laboratory in the United States have demonstrated this excess noise for measured natural turbulence and compared it with turbulent inflow noise calculations (Moriarty, 2004). Below 200 Hz, the turbulent inflow noise dominates over all other aerodynamic sources for turbulent intensities above 10%. No account of this excess noise is included in any noise regulation.

The use of masking noise to justify an increase of the noise limit with wind speed was laid to rest by the pioneering work of van den Berg (2004). He argued that in a stable atmosphere there can be a large vertical wind speed gradient such that the turbine is generating power and noise while at ground level there is insufficient wind to generate masking noise. He supported his argument with meteorological tower wind speed measurements. At that time, only the Netherlands, New Zealand, and Ontario were permitting wind developers to use the masking noise allowance. The Netherlands and New Zealand have since dropped the allowance. Ontario persists but since October 2008 (Ministry of the Environment, 2008) does require that developers justify its use by making on-site wind speed gradient measurements. Needless to say, the developers are not able to justify its use. The pity of it is that so many wind farms have been built with setbacks based on the allowance years after van den Berg had so clearly made his case.

The Way Ahead

At a minimum, the following need to be introduced into noise regulation of wind turbines.

The noise limit needs to be reduced to 35 dBA at nighttime and, where applicable, reduced to 40 dBA for daytime. This is still intrusive in rural areas but will help bring setbacks to those recommended by health authorities. Wind energy and the wind industry have flourished in Germany with these regulations, despite a population density 20 times that of Ontario.

A penalty of 5 dBA needs to be added to the time-average predicted noise levels; this is to compensate for the enhanced audibility of the amplitude-modulated and impulsive character of turbine noise.

Uncertainty in design calculations is the norm in engineering practice. The ±4 dBA is real and should be tolerated in the noise prediction calculation. For the wind developers, erring on the side of caution could protect their very large investments when testing for compliance does become the norm.

A great deal is known about the excess noise due to turbulent inflow. Wind energy developers need to make test tower measurements of local natural turbulence and make calculations of wake turbulence to predict this excess noise.

Compliance is not so difficult. It is common practice to check for compliance in all manner of industrial situations. Atkinson & Rapley Consulting (2011), is association with Astute Engineering, in New Zealand has developed a fully automatic environmental noise measurement system. This is in service in New Zealand for compliance testing of wind turbine noise. Compliance testing is vital because it leads to reconsideration of noise prediction calculations. Where noise audits have been done, such as that at a home near Shelburne in Ontario, turbine noise well in excess of the noise limit has been demonstrated. In such cases, the wind energy company pays compensation or buys out the home-owner; no iterative use is made of the audit.

With the above changes to the regulation of noise: a 35 dBA nighttime noise limit, penalties of 5 dBA for the periodic or impulsive character of turbine noise, 4 dBA for uncertainty in noise prediction, and a penalty for turbulent inflow noise the setback from homes will approach the 1.5 to 2 kilometers recommended by health authorities.

Offshore Turbine Noise

At present there are no freshwater offshore wind farms and therefore no reported adverse health effects. Nevertheless, they are under consideration for Great Lakes both north and south of the border. It is our common experience that sound propagates readily over water and therefore it is expected that turbine noise will be a bigger problem for offshore wind farms. The science of noise from offshore wind turbines has been reviewed in a report for the Danish Ministry of the Environment (Søndergaard & Plovsing, 2005). They emphasize the "Swedish Model" (2001), which allows for a transition from spherical spreading to cylindrical spreading beyond a certain distance from the turbine. As noted above, the cylindrical spreading results from refractive reflection from the atmosphere and reflection from the water as a hard surface. The transition distance is a parameter that depends on the wind speed and temperature gradients.

This Swedish propagation model, for distances larger than a transition distance d, is written as

$$L = L_s - 20\log(r) - 11 + 3 - \Delta L_a + 10\log\left(\frac{r}{d}\right),$$

where L is the sound pressure level at the observer, L_s is the turbine sound power (e.g., 105 dBA), 11 is 10 log(4π), 3 is 3 dBA of ground reflection, ΔL_a is the integrated frequency dependent absorption coefficient, a function of r, and r is the distance from turbine hub to the observer. The second term on the right gives the spherical spreading and the final term corrects for cylindrical spreading beyond the distance d. Søndergaard and Plovsing (2005) have calculated the integrated absorption coefficient and show the result in figure 17 of their report. For instance, at a distance of 5 kilometers, it is 8 dBA. The transition distance for the onset of cylindrical spreading was uncertain but was assumed to be less than 1 kilometer.

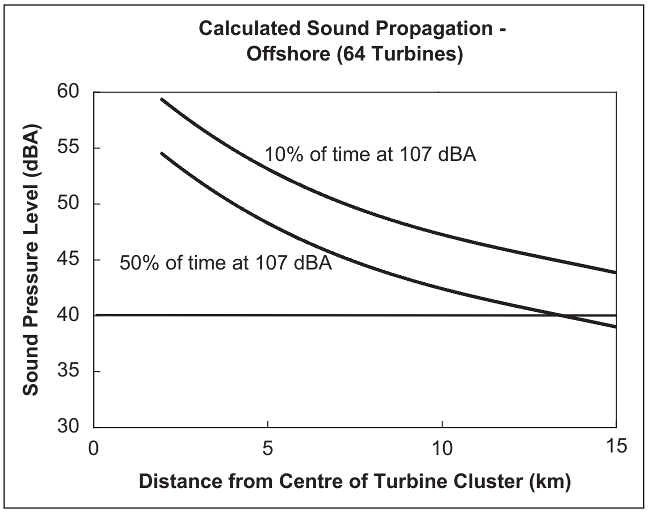

Figure 2. Predicted sound pressure level versus distance from group of 64 offshore turbines

The work of Søndergaard and Plovsing (2005) was followed up by sound propagation experiments over sea in the Kalmar Strait between Sweden and the Öland island in the Baltic Sea (Boué, 2007). The separation between source and receiver was 9.7 kilometers. Measurements of *average* sound transmission loss showed agreement with the Swedish propagation model with a transition distance of 700 meters for the break between spherical and cylindrical spreading. Furthermore, the measured TL(90), the transmission loss exceeded 90% of the time, was in agreement with the Swedish propagation model with the 200 meter transition distance. Therefore, Boué's measurements allow a reliable estimate of the sound pressure level as a function of distance over water from a turbine. Interestingly, Dickinson (2010) in New Zealand has found the break point of 750 meters for turbine noise propagation over land.

At large distances, such as 5 kilometers, the path difference between the direct and reflected pathways from turbine to receptor become small. For instance, at a distance of 5 kilometers, the path difference is equal to or less than a quarter wavelength for frequencies ≤1700 Hz. That is, for the spectrum of sound that reaches a receptor the direct and reflected sound waves add coherently. This adds 3 dB to the sound pressure level.

A numerical example demonstrates the difference between sound propagation over land and water. Figure 2 shows the predicted sound pressure level as a function of distance from a group of 64 offshore turbines. The example uses the Siemens 2.3 MW turbines, which reach their maximum sound power level of 107 dBA when the electrical power output is just 25% of the turbine nameplate power output. The wind farm will have some extension of course. The distance is the mean distance from the group. The lower curve is based on the average transition distance of 700 meters determined by Boué; the upper curve corresponds to the sound pressure level expected for 10% of the time that the turbines are operating at a capacity factor of 25% or greater. For the "worst case scenario" the setback of the wind farm needs to be 20 kilometers offshore.

Conclusion

Wind turbines are noisy and cause annoyance in about 20% of residents living within a distance considered acceptable by regulatory authorities. For many of this 20%, the annoyance and sleep disturbance leads on to adverse health effects. This is a far larger proportion than for those living with traffic and industrial noise at the same level. The annoyance and adverse health effects are attributable to the character of turbine noise and to deficiencies in noise regulations. Specifically, given the amplitude modulation, the allowed intrusion above ambient is far too high; there is no account taken of uncertainty in the prediction of noise at a home; there is no account taken for the excess noise caused by turbulent inflow, both natural and up-wind turbine wake; and the lack of compliance testing leaves the adverse health effects to compound from one completed wind farm to the next one being designed.

Declaration of Conflicting Interests

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Bio

John P. Harrison has expertise in the properties of matter at low temperatures with emphasis on high frequency sound waves (phonons). For the past 5 years he has studied wind turbine noise and its regulation. He has presented invited talks on the subject at 3 conferences, including the 2008 World Wind Energy Conference.

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Literature Reviews on Wind Turbines and Health: Are They Enough?

Brett Horner[1], Roy D. Jeffery[2], and Carmen M. E. Krogh[1]

Abstract

Industrial wind turbines (IWTs) are a new source of community noise to which relatively few people have yet been exposed. IWTs are being erected at a rapid pace in proximity to human habitation. Some people report experiencing adverse health effects as a result of living in the environs of IWTs. In order to address public concerns and assess the plausibility of reported adverse health effects, a number of literature reviews have been commissioned by various organizations. This article explores some of the recent literature reviews on IWTs and adverse health effects. It considers the completeness, accuracy, and objectivity of their contents and conclusions. While some of the literature reviews provide a balanced assessment and draw reasonable scientific conclusions, others should not be relied on to make informed decisions. The article concludes that human health research is required to develop authoritative guidelines for the siting of IWTs in order to protect the health and welfare of exposed individuals.

Keywords

wind turbines, adverse health effects, literature reviews

Introduction

Industrial wind turbines (IWTs) are promoted as a clean, renewable source of energy generation. In response to environmental concerns, many jurisdictions have incorporated IWT development as a component of their energy mix.

Noise regulations can have a significant impact on wind turbine spacing, and therefore the cost of wind generated electricity (Canadian Wind Energy Association, 2004). To obtain access to the transmission grid IWTs are being sited in close proximity to human habitation (Hornung, 2010). Some individuals are reporting experiencing adverse health effects resulting from living in the environs of IWTs.

The discussion presented in this article is based on the content and conclusions of some of the available literature reviews on the subject of IWTs and adverse health effects. This article is not a literature review. The intention is to consider the completeness, accuracy, and objectivity of the contents of some reviews.

While this article discusses some of commonly cited literature reviews produced in the past few years, it is not intended to be exhaustive. The literature reviews considered have been produced in North America and Australia.

There is no intention to focus on any author. Some (co) authors cited in this article have participated in more than one of the literature reviews considered.

Setting the Stage

IWTs are elevated sound sources visible from afar and hence intrude both visually and aurally into private space. IWTs are also a new source of community noise to which relatively few people have yet been exposed (Pedersen, Bakker, Bouma, & van den Berg, 2009).

There are reports of individuals experiencing adverse health effects attributed to exposure to IWTs in media reports, official reports (Hansard, 2009), and case studies (Harry, 2007; Krogh, Gillis, Kouwen, & Aramini, 2011; Nissenbaum, 2009; Phipps, Amati, McCoard, & Fisher, 2007; Pierpont, 2009; Shepherd, McBride, Welch, Dirks, & Hill, 2011; Thorne, 2011). Examples of reported adverse health effects include annoyance, sleep disturbance, stress or psychological distress, inner ear symptoms, headaches, excessive tiredness, and reduction of quality of life.

The World Health Organization (WHO, 1948) definition of health has been accepted by many jurisdictions including the Canadian federal, provincial, and territorial governments and health officials (Health Canada, 2004, vol. 1, p. 1-1): "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

IWT-induced annoyance, stress, sleep disturbance, other reported psychological or physiological symptoms and reduced quality of life constitute adverse health effects under the WHO definition of health.

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These reports have raised concerns that IWTs be sited in a manner that prevents negative health impacts. In recent years, a number of literature reviews on the subject of IWTs and adverse health effects have been convened in order to address these concerns.

Chatham-Kent Public Health Unit–Canada

In June 2008, the Chatham-Kent Public Health Unit released a literature review titled "The Health Impact of Wind Turbines: A Review of the Current White, Grey, and Published Literature." Some of the IWT issues discussed included structural and blade failure, ice throw, noise, shadow flicker, and construction injuries.

The literature review discusses the benefits of wind energy and informs the reader that the Chatham-Kent Official Plan states,

> It shall be the objective of Chatham-Kent to: encourage the development of wind energy systems for electricity production, as a source of renewable energy for the economic and environmental benefit of Chatham-Kent and the Province of Ontario.

Chatham-Kent Public Health Unit (2008) states that wind power has no harmful pollutants. However, one of the references cited to support this assertion, that is, WHO (2004), does acknowledge that IWT ". . . noise pollution may be a problem if turbines are situated close to centres of population."

Chatham-Kent Public Health Unit (2008) states, "Wherever possible, peer reviewed journals were utilized as the first information source in efforts to reduce potential bias" (p. 5) However, a number of relevant peer-reviewed articles available at the time of the literature review were omitted from the reference list. Examples include Pedersen and Persson Waye (2007, 2008), and G. P. van den Berg (2003). In addition, the literature review citations primarily include non–peer-reviewed references, many of which are produced for, or by, members of the wind energy industry. For example, numerous citations are from the works of the Canadian, American, British, and Danish wind energy associations or their listed members.

Chatham-Kent Public Health Unit (2008) acknowledges noise and sound can be annoying and states, "wind turbine noise is comparatively lower than road traffic, trains, construction activities, and industrial noise." However, it does not inform readers that IWT noise is found to be more annoying than other equally loud sources of noise including transportation noise and industrial noise or that sleep disturbance from IWT noise can occur (Pedersen & Persson Waye, 2004, 2007; F. van den Berg, Pedersen, Bouma, & Bakker, 2008).

Chatham-Kent Public Health Unit (2008) closes by stating,

> This paper concludes and concurs with the original quote from Chatham-Kent's Acting Medical Officer of Health, Dr. David Colby,
>
> In summary, as long as the Ministry of Environment Guidelines for location criteria of wind farms are followed, it is my opinion that there will be negligible adverse health impacts on Chatham-Kent citizens. Although opposition to wind farms on aesthetic grounds is a legitimate point of view, opposition to wind farms on the basis of potential adverse health consequences is not justified by the evidence.

Although Chatham-Kent's Acting Medical Officer (personal communication, May 6, 2009) is not the author of the literature review, he has stated that he endorsed it and takes full responsibility for the contents.

In a 2009 reference, the Acting Medical Officer of Health Chatham-Kent Health Unit stated,

> ... fluctuating aerodynamic noise is the cause of most noise complaints regarding wind turbines, as it is harder to become accustomed to fluctuating noise than to noise that does not fluctuate. The noise limits imposed by the Ministry of the Environment for wind turbines are designed to prevent noise issues but some wind turbines produce noise levels that may be irritating and even stressful to some people who are more sensitive to noise. Sleep disturbance can occur. Others exposed to the same noise levels may experience no difficulty. There is no evidence of direct effects to health by this level of noise but there could be indirect effects from annoyance-induced stress. (p. 3)

IWT-induced annoyance and sleep disturbance has been documented to occur at sound pressure levels permitted by Ontario IWT noise guidelines (Ministry of the Environment, Ontario, 2008; Pedersen & Persson Waye, 2004).

Notably, Chatham-Kent Public Health Unit (2008) omits discussion of amplitude modulation in modern upwind turbines, sleep disturbance, and annoyance-induced stress. The literature review cites Leventhall (2006), noting the reference discounts IWT infrasound as a health concern. However, Chatham-Kent Public Health Unit (2008) omits informing readers that Leventhall (2006) identified amplitude modulation as the noise which requires attention, both to reduce it and to develop optimum assessment methods.

Chatham-Kent Public Health Unit (2008) mentions research conducted by Dr. Nina Pierpont noting, "One cannot discount the information, yet it is prudent that generalizations from such limited data are avoided." Chatham-Kent Public Health Unit omits discussion of the specifics of Dr. Pierpont's research.

Dr. Pierpont's results were published in her 2009 book. She described an array of symptoms documented in her case study of individuals exposed to IWTs:

> Symptoms include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering when awake or asleep. (p. 26)

Dr. Pierpont proposes a hypothesis regarding causation and acknowledges that additional research is required.

A 2010 presentation by the Acting Medical Officer of Health Chatham-Kent Health Unit states,

> Dr Pierpont has not made new discoveries.
>
> She is describing stress effects of low level noise, which occur with a small number of people.
>
> These effects have been published a number of times previously and are well known to those experienced at the "street level" of environmental noise problems.
>
> It appears that there is no specific Wind Turbine Syndrome, but there are stress effects from low levels of noise, either high frequency or low frequency noise, which affect a small number of people. It is the audible swoosh-swoosh which, when it occurs, is the cause, not infrasound or low frequency noise.

Minnesota Department of Health–United States

In May 2009, the Minnesota Department of Health Environmental Health Division released "Public Health Impacts of Wind Turbines." The literature review focuses predominately on IWT noise and vibration but also discusses IWT shadow flicker, that is, the casting of moving shadows on the ground as the wind turbine blades rotate.

A brief overview of the characteristics of sensory systems and sound is followed by a discussion of the characteristics of IWT noise. In addition, the literature review discusses specific IWT noise issues including difficulties in accurately modeling IWT noise levels, nighttime noise issues, effects of wind shear, modulation of aerodynamic noise, and low-frequency noise.

IWT shadow flicker is also discussed noting that it can cause annoyance and driver distraction, and can be an issue both indoors and outdoors when the sun is low in the sky. It notes flicker should not be an issue at distances over 10 rotational diameters or approximately 1,000 meters, which is a recommended setback distance. Detailed shadow flicker modeling is also recommended during the planning stage of an IWT project.

Studies of IWT impacts on people are summarized. The Minnesota Department of Health (2009) discusses both peer-reviewed literature and nonreviewed case reports which catalogued complaints of annoyance and other health impacts associated with IWTs. Case report summaries of Harry (2007), Phipps et al. (2007), The Large Wind Turbine Citizens Committee for the Town of Union (2008), and Pierpont (2009) are included in the literature review.

The Minnesota Department of Health (2009) notes that lower noise levels,

> . . . from wind turbines engenders annoyance similar to much higher levels of noise exposure from aircraft, road traffic and railroads. Sound impulsiveness, low frequency noise and persistence of the noise, as well as demographic characteristics may explain some of the difference. (pp. 19-20)

It states in its conclusion,

> The most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life. Sleeplessness and headache are the most common health complaints and are highly correlated (but not perfectly correlated) with annoyance complaints. Complaints are more likely when turbines are visible or when shadow flicker occurs. Most available evidence suggests that reported health effects are related to audible low frequency noise. Complaints appear to rise with increasing outside noise levels above 35 dB(A). It has been hypothesized that direct activation of the vestibular and autonomic nervous system may be responsible for less common complaints, but evidence is scant. (p. 25)

Minnesota Department of Health (2009) received a Notable Document Award for excellence in exploring topics of contemporary interest to legislators from the Legislative Research Librarians staff section of the National Conference of State Legislatures (National Conference of State Legislatures, 2010, http://www.ncsl.org/?tabid=16066)

AWEA/CanWEA Panel Review–United States/Canada

In response to publicized concerns that the sounds emitted from wind turbines cause adverse health consequences, industry trade associations, the American Wind Energy Association (AWEA), and Canadian Wind Energy Association (CanWEA), funded a literature review titled, "Wind Turbine Sound and Health Effects: An Expert Panel Review" (Colby et al., 2009).

The literature review focuses its discussion on IWT sound and does not address, in detail, other IWT impacts such as shadow flicker.

The Colby et al. (2009) Conclusions section states, "1. Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans." (p. 5-2). However, the contents of the literature review acknowledge IWT noise may cause annoyance, stress, and sleep disturbance and as a result people may experience adverse physiological and psychological symptoms (p. 4-3, p. 4-10, p. 5-2).

Colby et al. (2009) lists symptoms which Dr. Nina Pierpont coined as "wind turbine syndrome" stating,

> Symptoms included sleep disturbance, headache, tinnitus, ear pressure, vertigo, nausea, visual blurring, tachycardia, irritability, concentration, memory, panic attacks, internal pulsation, and quivering.
>
> . . . these so called "wind turbine syndrome" symptoms are not new and have been published previously in the context of "annoyance" to environmental sounds. . . . The following symptoms are based on the experience of noise sufferers extending over a number of years: distraction, dizziness, eye strain, fatigue, feeling vibration, headache, insomnia, muscle spasm, nausea, nose bleeds, palpitations, pressure in the ears or head, skin burns, stress, and tension . . . (pp. 4-9, 4-10)

In reference to "wind turbine syndrome" symptoms Colby et al. (2009) coauthor Dr. Geoff Leventhall stated,

> I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise. . . . what Pierpont describes is effects of annoyance by noise—a stress effect, not the direct physiological effect which she claims, as it has been shown above that these claims are without substance. What Pierpont describes are simply the well known effects of persistent, unwanted noise, and use of the words "Wind Turbine Syndrome" should be discontinued, in order to avoid confusion. (*PSC Ref#121877 20: Wind Turbine Syndrome: An appraisal*, 2009, pp. 9-10)

The forgoing citations appear to contradict the Colby et al. (2009) conclusion that "Sound from wind turbines does not pose a risk of . . . any other adverse health effect in humans." (p. 5-2)

In March 2011, Dr. Leventhall testified under oath that the Colby et al. (2009) Conclusion "1" would be more clearly worded by adding the words, "direct physiopathological effects" (Erickson v. Director, Ministry of the Environment, 2011b), that is, sound from wind turbines does not pose a risk of hearing loss or any other direct physiopathological effect in humans. This addition of the words "direct physiopathological" is an important distinction which alters the fundamental meaning of one of the literature review's main conclusions.

The authors also conclude that "2. Subaudible, low frequency sound and infrasound from wind turbines do not present a risk to human health" (Colby et al., 2009, p. 5-2). However, the literature review also acknowledges that "No scientific studies have specifically evaluated health effects from exposure to low frequency sound from wind turbines" (Colby et al., 2009, p. 3-17). In the absence of specific scientific studies, it is difficult to draw a definitive conclusion.

In its discussion of IWT low frequency noise, Colby et al. (2009) states,

> According to a report of the National Research Council (NRC), low frequency sound is a concern for older wind turbines but not the modern type (National Research Council, 2007). (p. 3-17)

National Research Council (2007) does not appear to support the above statement. In reference to IWTs and low-frequency noise the National Research Council (2007) states,

> Low-frequency vibration and its effects on humans are not well understood. Sensitivity to such vibration resulting from wind-turbine noise is highly variable among humans. Although there are opposing views on the subject, it has recently been stated (Pierpont 2006) that "some people feel disturbing amounts of vibration or pulsation from wind turbines, and can count in their bodies, especially their chests, the beats of the blades passing the towers, even when they can't hear or see them." More needs to be understood regarding the effects of low-frequency noise on humans. . . . studies on human sensitivity to very low frequencies are recommended. (pp. 158-159, p. 176)

Colby et al. (2009) in their Conclusions state, "3. Some people may be annoyed at the presence of sound from wind turbines. Annoyance is not a pathological entity" (p. 5-2).

However, under oath Dr. Leventhall acknowledged that based on the information he had submitted, it would be fair to change Conclusion "3" from some people "may be" annoyed, to some people "will be" annoyed at the presence of sound from wind turbines. (Erickson v. Director, Ministry of the Environment, 2011b)

The final Conclusions states, "4. A major cause of concern about wind turbine sound is its fluctuating nature. Some may find this sound annoying, a reaction that depends primarily on personal characteristics as opposed to the intensity of the sound level." (p. 5-2)

However, Leventhall (2006, p. 34) discusses IWT amplitude modulation:

> Attention should be focused on the audio frequency fluctuating swish, which some people may well find to be very disturbing and stressful, depending on its level.

> The usual equivalent level measurements and analyses are incomplete, as these measurements are taken over a time period which is much longer than the fluctuation period and information on the fluctuations is lost. A time varying sound is more annoying than a steady sound of the same average level and this is accounted for by reducing the permitted level of wind turbine noise. However, more work is required to ensure that the optimum levels have been set.

Leventhall (2006) does not state that human response to amplitude modulation was primarily influenced by an individual's attitude but rather depends on its level/intensity. Consequently Conclusion "4" of Colby et al. (2009) appears to contradict Leventhall (2006).

In 2011, Dr. Leventhall affirmed the contents of Leventhall (2006) testifying there are no changes he would like to make to his 2006 article. (Erickson v. Director, Ministry of the Environment 2011b)

Colby et al. (2009) discuss how the first indication that an exposure might be harmful comes from the informal observations of doctors who notice a possible correlation between an exposure and a disease, then communicate their findings to colleagues in case reports, or reports of groups of cases (case series).

Based on its analysis of case reports, this literature review states in its Conclusions section,

> Panel members agree that the number and uncontrolled nature of existing case reports of adverse health effects alleged to be associated with wind turbines are insufficient to advocate for funding further studies. (Colby et al., 2009, p. 5-2)

However, Colby et al. (2009) limit their discussion to only two of the case studies available at the time of their publication. Case studies omitted from the literature review include the following: Krogh, Gillis, and Kouwen (2009), Nissenbaum (2009), Harry (2007), and Phipps et al. (2007).

Colby et al. (2009) suggests the "nocebo effect" may be a possible cause of reported IWT adverse health effects.

A keyword search of "nocebo" in *Noise and Health Journal* (as cited July 10, 2010), and WHO's *Guidelines for Community Noise* (Berglund, Lindvall, & Schwela, 1999) and *Night Noise Guidelines for Europe* (2009) yields no results. A keyword search of "nocebo" in peer-reviewed literature on the subject of human response to wind turbine noise returns no results. Research demonstrates individuals initially welcomed IWTs into their communities and the reported adverse impacts were unexpected (Krogh, 2011, p. 330).

National Collaborating Centre for Environmental Health–Canada

In January 2010, the National Collaborating Centre for Environmental Health (Canada), published an article, "Wind Turbines and Health" (Rideout, Copes, & Bos, 2010).

The first page contains a summary of findings and states, "The sound level associated with wind turbines at common residential setbacks is not sufficient to damage hearing, but may lead to annoyance and sleep disturbance" (p. 1).

This literature review also notes that "Annoyance and sleep disruption are common when sound levels are 30 to 45 dBA" (p. 4).

Citing Pierpont (2009), this literature review notes that a range of symptoms including dizziness, sleep disruption, and headaches have been attributed to wind turbines but it does not elaborate.

The literature review cites Colby et al. (2009) noting that IWT sound will not damage hearing. However, omitted is the Colby et al. (2009) acknowledgment that reported health effects are the result of stress from noise annoyance.

In earlier references, authors Copes and Rideout (2009a, 2009b) identified that IWT noise and/or aesthetics and/or shadow flicker may cause stress. However, these acknowledgments of stress are omitted from Rideout et al. (2010).

Both Rideout et al. (2010) and Copes and Rideout (2009a) list a number of key gaps. Some of the gaps identified include

- stress-induced health effects from noise, visual impact, shadow flicker
- health effects from long-term exposure to low levels of low-frequency sound
- practical measurement methods for attributing sound specifically to wind turbines
- impact of wind turbine sound on sleep physiology
- dizziness and migraine from shadow flicker
- risk of ice throw in regions where glaze ice is common (most research has focused on rime ice)
- research to measure the efficacy of currently used setbacks to prevent injury
- epidemiological data to assess health status before and after wind farm development

In spite of these acknowledged gaps Rideout et al. (2010) do not make an appeal for new research.

Chief Medical Officer of Health–Canada

On May 20, 2010, the Chief Medical Officer (2010a) of Health of Ontario released "The Potential Health Impact of Wind Turbines." This literature review discusses a number of IWT issues including the following: the main research data available to date on wind turbines and health, sound and noise, low-frequency sound, infrasound and vibration, sound exposure assessment, electromagnetic fields, shadow flicker, ice throw and ice shed, and structural hazards.

Chief Medical Officer of Health (2010a) cites "four cross-sectional studies, published in scientific journals, which investigated the relationships between exposure to wind turbine noise and annoyance in large samples of people (351 to

1,948) living in Europe near wind turbines" (p. 5). The literature review goes on to state that the studies found,

> The sound was annoying only to a small percentage of the exposed people; approximately four to ten per cent were very annoyed at sound levels between 35 and 45 dBA. (Chief Medical Officer of Health, 2010a, p. 6)

However, the Chief Medical Officer of Health (2010a) omitted results from Swedish studies, the respondents who were "rather" annoyed, and the respondents who reported annoyance when spending time outdoors at their dwelling. Therefore, based on a peer-reviewed body of research, reporting a range of at least 5% to 28% would have been more accurate (Pedersen et al., 2009; Pedersen & Persson Waye, 2004).

Of significance, a 2010 final draft report prepared for the Ontario Ministry of Environment states,

> The audible sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, is nonetheless expected to result in a nontrivial percentage of persons being highly annoyed. As with sounds from many sources, research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons. (Howe Gastmeier Chapnik Limited, 2010, p. 39)

Chief Medical Officer of Health (2010a) discusses Pierpont (2009) but omits discussion of other case studies including Nissenbaum (2009), Harry (2007), and Phipps et al. (2007). WindVOiCe (Krogh et al., 2009) is included in the reference list; however, there is no discussion of the Ontario-based health survey. Prior to the release of the literature review, the Chief Medical Officer of Health of Ontario, Dr. Arlene King, had been informed of the results of the Krogh et al. (2009) survey (Teleconference, 2009, November 23). Just prior to the release of the literature review the Office of the Chief Medical Officer of Health of Ontario was advised, by e-mail, of updated WindVOiCe results. At that time the survey documented approximately 100 Ontario residents reporting adverse health effects (Krogh, Gillis, & Kouwen, 2010).

Chief Medical Officer of Health (2010a) discusses the symptoms documented in Dr. Pierpont's case study, that is, "wind turbine syndrome" and concludes,

> While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. (p. 10)

The use of the word "direct" by the Chief Medical Officer of Health (2010a) ignores the possibility of indirect adverse health effects from IWT noise. The lead author of this literature review acknowledged under oath that Chief Medical Officer of Health (2010a) only looked at direct links (Erickson v. Director, Ministry of the Environment, 2011a) and in addition, the report:

> . . . did not say that there is no sleep disturbance, it said that there is no direct link to the sleep disturbance. So if annoyance has caused the sleep disturbance, we are not saying that that could not have happened. (Erickson v. Director, Ministry of the Environment, 2011a)

Chief Medical Officer of Health (2010a) cites Colby et al. (2009) but does not disclose that this reference attributes "wind turbine syndrome" symptoms to be stress responses associated with noise annoyance. Chief Medical Officer of Health (2010a) omits discussion of potential stress impacts.

One of the main conclusions of the Chief Medical Officer of Health (2010a) is "The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct adverse health effects" (p. 6).

This statement that "other direct adverse health effects" will not be caused by exposure to wind turbine sound is not supported by the studies reviewed by the Chief Medical Officer of Health (2010a) which consider the relationship between residential exposure to IWT sound and human health.

Chief Medical Officer of Health (2010a) does acknowledge the unique characteristics of IWT noise, and the unique human response to IWT noise, stating, "Wind turbine noise was perceived as more annoying than transportation or industrial noise at comparable levels, possibly due to its swishing quality, changes throughout a 24 hour period, and lack of night-time abatement." (p. 6)

From various studies it follows that this swishing (modulation) is equivalent in annoyance to the unmodulated sound at an approximately 5 dB higher level (Pedersen & van den Berg, 2010).

Ontario Guidelines require a 5 dBA adjustment for other industrial noise that has amplitude modulation (Ministry of the Environment, Ontario, n.d.); however, there is no such adjustment for IWT amplitude modulation (Ministry of the Environment, Ontario, 2008). Chief Medical Officer of Health (2010a) does not address this disparity.

Chief Medical Officer of Health (2010a) also concludes,

> Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects (p. 10).

This conclusion is not supported by other references listed in the report of Chief Medical Officer of Health (2010a). For example, the literature review of Minnesota Department of

Health (2009) suggests that reported health effects are related to audible low-frequency noise.

Colby et al. (2009) acknowledge that "No scientific studies have specifically evaluated health effects from exposure to low frequency sound from wind turbines" (p. 3-17).

Furthermore, Chief Medical Officer of Health (2010a) acknowledges that the Ontario Ministry of the Environment had recently hired consultants to review low-frequency sound impacts from wind turbines and develop recommendations regarding low-frequency sound. The consultant's final draft report on IWT low-frequency noise and infrasound states that "There is a degree of disagreement and uncertainty in the literature of some of the subjects discussed in this review, and research efforts are ongoing" (Howe Gastmeier Chapnik Limited, 2010, p. 41) The report also acknowledges that IWT low-frequency noise can be an issue and recommends the adoption or development of a protocol to provide guidance for addressing such complaints (Howe Gastmeier Chapnik Limited, 2010).

Under oath the lead author of the report of Chief Medical Officer of Health (2010a) stated that

> . . . there is definitely recognition that low frequency sound could produce annoyance and the sensitivity to annoyance to low frequency sound could be greater than to audible sounds. (Erickson v. Director, Ministry of the Environment, 2011a)

Annoyance from audible low-frequency noise is acknowledged to be more severe in general. Low-frequency noise does not need to be considered loud for it to cause annoyance and irritation (DeGagne & Lapka, 2008). Low-frequency noise causes immense suffering to those who are unfortunate to be sensitive to it (Leventhall, 2003) and chronic psychophysiological damage may result from long-term exposure to low-level low-frequency noise (Leventhall, 2004). Some symptoms associated with exposure to low-frequency noise include stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, anxiety, heart ailments, and palpitation (DeGagne & Lapka, 2008; Leventhall, 2003; Schust, 2004).

The report of the Chief Medical Officer of Health (2010a) contains a section on Ontario IWT setbacks which states,

> Provincial setbacks were established to protect Ontarians from potential health and safety hazards of wind turbines including noise and structural hazards.

Analysis of this section suggests that the authors lack a thorough understanding of the existing Ontario IWT setbacks.

For example, Chief Medical Officer of Health (2010a) states,

> . . . a wind project with five turbines, each with a sound power level of 107dB, must have its turbines setback at a minimum 950 m from the nearest receptor.

The above use of the term *must* is incorrect. Ontario regulations permit IWTs to be sited as close as 550 m if the developer submits a report prepared in accordance with the publication of the Ministry of the Environment titled "Noise Guidelines for Wind Farms" (Environmental Protection Act, Ontario Regulation 359/09).

Chief Medical Officer of Health (2010a) also states that setbacks are based on modeling of sound produced by wind turbines and are intended to limit sound at the nearest residence to no more than 40 dB. It does not inform readers that Ontario IWT Noise Guideline permit in principle, levels up to 51 dBA at a residence 24 hours a day (Ministry of the Environment, Ontario, 2008). The 51 dBA permitted by Ontario guidelines is significantly higher than the 40 dB that the report of the Chief Medical Officer of Health (2010a) indicates is recommended to protect public health from community noise.

In 2011, when questioned about the 40 dB noise limit the lead author of the report of the Chief Medical Officer of Health (2010a) acknowledged that it was not developed based on IWT noise research but rather on traffic, rail, and aircraft noise. Furthermore, when asked to comment on the approved Ontario IWT noise limits of up to 51 dBA the lead author testified she would not like to speculate on numbers above 40 dBA (Erickson v. Director, Ministry of the Environment, 2011a).

Of interest, in 2009 the lead consultant of the report which led to the 2008 Ontario IWT noise guidelines declined to comment on IWTs and health stating,

> I am not a medical doctor or a psychoacoustician or a physiological acoustician. I am an acoustician from the engineering science perspective. So, to comment on health issues is outside my area of expertise. (personal communication, July 22, 2009)

The Chief Medical Officer of Health (2010a) acknowledges Ontario does not have a measurement protocol to verify actual IWT noise compliance with the modeled limits.

The Chief Medical Officer of Health (2010a) discusses IWT shadow flicker but limits the topic to photosensitive epilepsy noting that industrial turbines rotate at a speed below that which would trigger a seizure. However, the literature review does not mention that shadows cast by one turbine on another should not have a cumulative flash rate exceeding 3 per second (Harding, Harding, & Wilkins, 2008). Consideration of shadow flicker–induced annoyance is also omitted. As well, there is no mention that detailed shadow flicker modeling is a recommended practice (Minnesota Department of Health, 2009; National Research Council, 2007). The absence of Ontario regulations to minimize the impact of IWT shadow flicker is not addressed.

Wind turbine ice throw and structural failure are potentially severe public hazards to people or passing vehicles (Rideout et al., 2010). The Chief Medical Officer of Health (2010a) acknowledges that "injury is minimized with setbacks of 200 to 500 metres" but does not question the wisdom of Ontario's setbacks which permit wind turbines to be situated within approximately 50 m (blade length plus 10 m) of a public road, railways, and/or a nonparticipating property (Environmental Protection Act, Ontario Regulation 359/09).

Contributing authors reportedly commented that material that could have been included was left out of the report of the Chief Medical Officer of Health (2010a) (Jankowski, 2010).

Of interest, in previous works, some of the contributing authors of the report of the Chief Medical Officer of Health (2010a), acknowledge that IWT noise may cause annoyance and/or stress and/or sleep disturbance (Copes & Rideout, 2009a, 2009b; Rideout et al., 2010) and symptoms such as dizziness, headaches, and sleep disturbance are examples of the well-known stress effects of exposure to noise (Colby et al., 2009).

In addition to their literature review, the office of the Chief Medical Officer of Health of Ontario has produced other references on the topic of IWTs and health.

For example in October 2009, the Chief Medical Officer of Health of Ontario, issued a memorandum addressed to medical officers of Health and Environmental Health directors. The memorandum references the work of Dr. Copes stating that ". . . sound produced by wind turbines is sometimes found to be annoying to some people which may result in stress and sleep disturbance" (King, 2009).

The above acknowledgment that IWT noise annoyance may result in stress and sleep disturbance is omitted from the report of the Chief Medical Officer of Health (2010a).

Another document was prepared by the office of the Chief Medical Officer of Health and transmitted to Ontario medical officers of health by the chair of the Council of Ontario Medical Officers of Health on May 19, 2010 (personal communication, January 27, 2011). The document states,

> Although some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, available scientific evidence does not demonstrate a direct causal link to wind turbine noise. It is possible that these symptoms are a result of annoyance with the noise. (Chief Medical Officer of Health, 2010b)

The acknowledgment that it is possible that the reported symptoms such as dizziness, headaches, and sleep disturbance are the result of IWT noise–induced annoyance is another omission from the Chief Medical Officer of Health (2010a).

Salt and Hullar–United States

On June 16, 2010, Dr. Alec Salt and Dr. Timothy Hullar released their peer-reviewed literature review titled, "Responses of the ear to low frequency sounds, infrasound and wind turbines" (Salt & Hullar, 2010). This work was supported by a research grant from the National Institute on Deafness and Other Communication Disorders, National Institutes of Health.

Salt and Hullar (2010) discuss the physics of infrasound, the anatomy of the ear, the mechanics of low-frequency stimulation, and the mechanics of low-frequency stimulation. The literature review notes that most references dismiss IWT inaudible low-frequency noise or infrasound as an issue on the basis that the sound is not perceptible. However, the authors state that this perspective fails to take into account that the outer hair cells of the inner ear are stimulated at levels that are not heard. The authors note that this raises the possibility that exposure to the infrasound component of wind turbine noise could influence the physiology of the ear and more research is required before firm conclusions can be made.

Salt and Hullar (2010) state in their conclusions,

> Other sensory cells or structures in the inner ear, such as the outer hair cells, are more sensitive to infrasound than the inner hair cells and can be stimulated by low frequency sounds at levels below those that are heard. The concept that an infrasonic sound that cannot be heard can have no influence on inner ear physiology is incorrect.
>
> . . .
>
> Based on our understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and affects the quality of life in sensitive individuals, there is an urgent need for more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans (p. 8).

National Health and Medical Research Council–Australia

In July 2010, the National Health and Medical Research Council released a report titled "Wind Turbines and Health, A Rapid Review of the Evidence July 2010" (National Health and Medical Research Council, 2010a). In 11 pages this literature review discusses adverse health impacts of IWTs with a focus on the effects of infrasound, noise, electromagnetic interference, shadow flicker, and blade glint.

At the outset, the National Health and Medical Research Council (2010a) present the reader with a limited scope. It states,

> In particular the paper seeks to ascertain if the following statement can be supported by the evidence: There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines. This statement is supported by the 2009 expert literature review commissioned by the American and Canadian Wind Energy Associations. (Colby et al., 2009)

A National Health and Medical Research Council (personal communication, June 15, 2010) communication asserts that the literature review ". . . only uses the best available evidence, in the form of peer-reviewed scientific literature, to formulate its recommendations."

The contents of National Health and Medical Research Council (2010a) reveal a different reality. The quality of material cited in NHMRC (2010a) is questionable. For example, the literature review cites an internet posting contained on "croakey the Crikey health blog." At the same time a number of the existing relevant peer-reviewed articles relevant to IWTs and health were omitted from the reference list.

National Health and Medical Research Council (2010a) quotes Colby et al. (2009): "Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effects in humans." However, it does not advise the reader that Colby et al. (2009) also acknowledge IWT noise may cause annoyance, stress, and sleep disturbance.

National Health and Medical Research Council (2010a) also states,

> The opposing view is that noise from wind turbines produces a cluster of symptoms which has been termed Wind Turbine Syndrome (WTS).

The literature review omits the discussion that Colby et al. (2009) attribute the symptoms defined as "wind turbine syndrome" to be the stress effects of noise annoyance. While National Health and Medical Research Council (2010a) briefly mentions Dr. Pierpont's research it does not detail the documented symptoms and omits any discussion of other existing case studies.

National Health and Medical Research Council (2010a) states,

> . . . numerous reports have concluded that there is no evidence of health effects arising from infrasound or low frequency noise generated by wind turbines

One of the references cited to support this statement is WHO (2004). However, WHO (2004) does not evaluate the health impacts of IWT infrasound or low-frequency noise.

National Health and Medical Research Council (2010a) relies on Minnesota Department of Health (2009); however, it omits disclosing that this literature review concludes that most available evidence suggests the reported health effects are related to audible low-frequency noise.

National Health and Medical Research Council (2010a) also relies on a citation from a fact sheet, which states, "Findings clearly show that there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health." Canada's federal health agency, Health Canada, responded to this fact sheet, stating, "In fact, there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health" (Health Canada, 2009).

National Health and Medical Research Council (2010a) also quotes a reference by HGC Engineering which states,

> While a great deal of discussion about infrasound in connection with wind turbine generators exists in the media there is no verifiable evidence for infrasound and production by modern turbines.

However, National Health and Medical Research Council (2010a) omits a reference by the same authors which acknowledges modern IWTs do produce infrasound (Howe Gastmeier Chapnik Limited, 2006). In addition, HGC Engineering stated in 2010 that modern IWTs produce infrasound which may be audible or inaudible (Howe Gastmeier Chapnik Limited, 2010).

National Health and Medical Research Council (2010a) concludes by stating,

> There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines. (p. 8)

The authors do not specify what the potential impacts on humans are nor do they provide specifics of the planning guidelines which will minimize the impacts.

In a public statement, National Health and Medical Research Council (2010b), affirms the need for research recommending ". . . relevant authorities take a precautionary approach and continue to monitor research outcomes." However, the literature review makes no appeal for new research.

Discussion

Complete, Accurate, and Objective

Literature reviews can be useful tools for summarizing existing literature related to a particular topic. In order to be considered reliable a literature review must be complete, accurate, and objective.

Literature reviews assessing the potential health impacts of a new exposure must evaluate the totality of the evidence. The use of terminology such as "direct physiopathological effects" or "direct causal links" limits the discussion. Failure to carefully evaluate potential indirect causal pathways and the psychological harm of IWT exposure represent errors of omission. Annoyance, sleep disturbance, cognitive and emotional response, and stress are health effects that occur through the indirect pathway (WHO, 2009, figure 4). The health outcomes associated with the indirect pathway are significant:

> Physiological experiments on humans have shown that noise of a moderate level acts via an indirect pathway and has health outcomes similar to those caused by high noise exposures on the direct pathway. The indirect pathway starts with noise-induced

> disturbances of activities such as communication or sleep. (WHO, 2009, p. 138)

In January 2010, the NHS Knowledge Service of the U.K. National Health Service, released a critique of Colby et al. (2009) and concluded, "The link between psychological distress and physical symptoms has not been explored by this report." These observations are appropriate for the other literature reviews that omit an evaluation of the indirect pathway.

Most of the literature reviews discussed in this article share many of the same references. Some of the literature reviews indicate a preference for peer-reviewed research. However, due to the limited body of peer-reviewed literature, they ultimately rely predominately on citations from nonreviewed sources, case studies, and other literature reviews.

Many of the literature reviews omit evaluating most of the available case studies, limiting their discussion to Pierpont (2009). The practice of omitting the majority of case studies raises concerns of completeness and objectivity.

Authors have an inherent responsibility to ensure that they accurately reflect the contents of references cited. Literature reviews which inappropriately cite or misquote references should be viewed with caution.

Some governments have incorporated wind energy as a key component of their energy mix and economic policy. For example, the Ontario Government has passed legislation designed to encourage rapid implementation of renewable energy and has made substantial financial commitments to wind energy development (Government of Ontario, 2010; Green Energy and Economy Act, 2009). Reports, including internal government correspondence, document that some Ontario families reporting adverse health effects have abandoned their homes, or had their homes purchased by IWT developers (Braithwaite, 2009a, 2009b; Ministry of Environment, Ontario, internal e-mail, 2009). Other Ontario families reporting adverse health effects have been billeted by the local IWT developer for months at time (Hansard, 2009; Krogh et al., 2011). Ministry of Environment correspondence also describes how low frequency noise from Ontario IWT facilities resulted in annoyance, "sleep deprivation" and "uninhabitable" living conditions. (Ministry of the Environment, Ontario, internal emails, May 1, 2009, June 29, 2009). Another internal document cites a number IWT noise issues, including amplitude modulation, and concludes "It appears compliance with the minimum setbacks and the noise study approach currently being used to approve the siting of WTGs will result or likely result in adverse effects…" (Ministry of the Environment, Ontario, internal memorandum, April 9, 2010)

Meanwhile the Ontario Health Minister reportedly stated there is no evidence, whatsoever, that there is an issue related to turbines (Heath, 2010).

Claims of no evidence raise concerns regarding the objectivity of research initiatives convened by governments which have financial commitments to; or policies that support; the rapid implementation of IWTs.

Health Canada (2004) states, "Government's job is to provide citizens with accurate and appropriate information so that they can protect themselves" (p. 1-1). It follows that a literature review produced by public health officials should provide the public with complete and accurate information.

Arguably government health officials are not fulfilling their responsibilities to provide citizens with complete and accurate information if their literature reviews omit acknowledgments that IWT-induced annoyance or stress may be the cause of reported health effects.

The Acting Medical Officer of Health Chatham-Kent Health Unit and the Office of the Chief Medical Officer of Health have declined requests to meet with individuals reporting experiencing adverse health from IWTs (personal communications, 2009, 2011). The reluctance of public health officials to consult with individuals reporting health effects represents a significant obstacle to the advancement of knowledge on the issue.

In some cases, literature reviews with common contributing authors, were released only months apart but contain different contents and/or conclusions. These inconsistencies raise concerns of completeness, accuracy, and objectivity.

Literature review assertions that IWT regulations are protective of human health should be viewed with caution if, the authors misquote the regulations, acknowledge recommended noise limits are not designed for IWTs, or are unable to comment on maximum permitted IWT sound levels.

Conclusions presented in a literature review must be derived objectively based on the science available. A conclusion that states that the sound from IWTs does not pose a risk of any adverse health effect in humans is not scientifically credible.

NHS Knowledge Service (2010) discusses the contents of Colby et al. (2009) and concluded, "Overall, this review will probably not resolve this controversy as there was a lack of high-level evidence on which to base any solid conclusions."

Where Are We Now?

The current inventory of the peer-reviewed literature relevant to the topic of IWTs and adverse health effects is increasing. One of the main conclusions from the existing body of peer-reviewed literature is that IWT turbine noise is perceived to be more annoying than transportation noise or industrial noise at comparable sound pressure levels (Pedersen et al., 2009). In addition, a number of case studies have documented individuals living in the environs of IWTs who are reporting adverse health effects.

WHO (2001) has recognized the serious nature of noise: "The recognition of the noise as a serious health hazard as opposed to a nuisance is a recent development and the health effects of the hazardous noise exposure are now considered to be an increasingly important public health problem."

Annoyance is acknowledged to be an adverse health effect (Health Canada, 2005; Michaud, Keith, & McMurchy, 2005; Pedersen & Persson Waye, 2007; Suter, 1991)

Until recently, the serious health consequences of noise-induced annoyance have been underestimated. Maschke and Niemann (2007) confirm that chronic severe annoyance induced by neighbor noise must be classified as a serious health risk.

Of interest, several authors of IWT-related literature reviews accept the plausibility of the reported IWT health effects and acknowledge that IWT noise and/or visual impacts may cause annoyance and/or stress and/or sleep disturbance, which can have other consequences. It is also acknowledged that these adverse health effects can occur at common residential set-back and sound pressure levels.

Some authors conducting literature reviews have proposed plausible mechanisms suggesting that the health effects may be caused by IWT amplitude modulation, the lack of night-time abatement, temporal variability, audible low frequency noise, visual impact, shadow flicker, and economic impacts. Exposure to IWT infrasound is another plausible explanation. All these proposed mechanisms require appropriate investigation.

At this time the precise pathophysiological mechanism(s) for the reported adverse health effects is not settled but important new evidence is emerging. Recent references indicate that IWT noise issues such as amplitude modulation and audible low-frequency noise are becoming more significant as IWTs increase in size (Møller & Pedersen, 2011; Thorne, 2011). Recent recommendations to measure and monitor IWT low-frequency noise indicate advancement of our understanding of IWT noise issues (Howe Gastmeier Chapnik Limited, 2010; *The Social and Economic Impact of Rural Wind Farms*, 2011).

Leventhall (2004) notes ". . . authorities must accept that annoyance by low frequency noise presents a real problem which is not addressed by the commonly used assessment methods." It is now becoming apparent that the commonly adopted compliance-based noise audits, based on "A" weighted Leq, are unsatisfactory for amplitude modulation and low-frequency noise (Richarz, Richarz, & Gambino, 2011; Thorne, 2011).

In summary, some literature reviews provide a balanced assessment and attempt to draw reasonable scientific conclusions based on the totality of evidence. Other literature reviews lack completeness, accuracy, and objectivity and contribute little to inform the public about the potential health risks associated with living in the environs of IWTs. Literature reviews which contain errors of omission and/or errors of commission cannot be relied on to make informed decisions and should be amended or regarded with caution.

Conclusions

IWTs can cause harm to human health if they are sited too close to residents (Thorne, 2011; Krogh, 2011). This finding is confirmed in a July 2011 Ontario Environmental Review Tribunal Decision which also supports the value of additional research into the health impacts of IWTs. The Decision also expressed concern the precautionary principle had not been appropriately considered, noting Colby et al. (2009) and Chief Medical Officer of Health (2010a) are focused on direct health effects rather than the indirect pathway. (DeMarco & Muldoon, 2011 p. 195, p. 204, p. 205, p. 207).

Repetitive literature reviews are of little value when dealing with emerging technologies; particularly when there is an acknowledged lack of original research. Some authors acknowledge knowledge gaps (Minnesota Department of Health, 2009; Rideout et al., 2010) and that research is required (Salt & Hullar, 2010). At the other extreme, other authors specifically do not advocate for funding further studies (Colby et al., 2009). In their review of Colby et al. (2009) the NHS Knowledge Service (2010) concluded new studies are indeed needed and that these studies should include a careful evaluation of the psychological harms of noise exposure.

Our analysis indicates that while some of the literature reviews are helpful, none are sufficient to resolve the complex issues surrounding IWT health effects. Even the most recent of the literature reviews discussed, National Health and Medical Research Council (2010a), cannot be considered conclusive. In March 2011, the chief executive officer of National Health and Medical Research Council stated,

> We regard this as a work in progress. We certainly do not believe that this question has been settled. That is why we are keeping it under constant review. That is why we said in our review that we believe authorities must take a precautionary approach to this (*The Social and Economic Impact of Rural Wind Farms*, 2011)

WHO (Berglund et al., 1999) endorses the precautionary principle,

> In all cases, noise should be reduced to the lowest level achievable in a particular situation. Where there is a reasonable possibility that public health will be damaged, action should be taken to protect public health without awaiting full scientific proof.

A June 2011 Australian Senate committee investigating IWT and adverse health effects report recommended,

> . . . the Commonwealth Government initiate as a matter of priority thorough, adequately resourced epidemiological and laboratory studies of the possible effects of wind farms on human health. This research must engage across industry and community, and include an advisory process representing the range of interests and concerns. (*The Social and Economic Impact of Rural Wind Farms*, 2011)

The authors of this article acknowledge the urgent need for original independent third party research into the adverse health effects of IWTs. In the interim, the precautionary principle must be respected and IWTs should not be built in close proximity to human habitation and where reports of adverse health effects are being reported, the facility should be decommissioned until the situation is resolved.

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Wind Turbines Make Waves: Why Some Residents Near Wind Turbines Become Ill

Magda Havas[1] and David Colling[2]

Abstract

People who live near wind turbines complain of symptoms that include some combination of the following: difficulty sleeping, fatigue, depression, irritability, aggressiveness, cognitive dysfunction, chest pain/pressure, headaches, joint pain, skin irritations, nausea, dizziness, tinnitus, and stress. These symptoms have been attributed to the pressure (sound) waves that wind turbines generate in the form of noise and infrasound. However, wind turbines also generate electromagnetic waves in the form of poor power quality (dirty electricity) and ground current, and these can adversely affect those who are electrically hypersensitive. Indeed, the symptoms mentioned above are consistent with electrohypersensitivity. Sensitivity to both sound and electromagnetic waves differs among individuals and may explain why not everyone in the same home experiences similar effects. Ways to mitigate the adverse health effects of wind turbines are presented.

Keywords

wind turbine, dirty electricity, power quality, ground current, contact current, electrohypersensitivity, noise, infrasound, vibroacoustic disease, wind turbine syndrome

Introduction

With growing concern about climate change, the carbon budget, depletion of fossil fuels, air pollution from dirty coal, radiation from nuclear power plants, and the need for a secure energy supply, more attention and funding are being diverted to renewable energy. Among the various types of renewable energy, wind has received a lot of attention due, in part, to opposition from communities earmarked for wind turbines and from communities that have experienced wind turbines firsthand.

Some people who live near wind turbines report difficulty sleeping and various symptoms of ill health and attribute these problems to noise and shadow flicker—two elements they can perceive. Indeed the U.S. National Research Council (Risser et al., 2007) identify noise and shadow flicker as the two key impacts of wind turbines on human health and well-being.

Not all health agencies, however, recognize that sound waves from wind turbines may cause adverse health effects. Following a review of the literature, the Chief Medical Officer of Health for Ontario (2010), concluded

> that while some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects. The sound level from wind turbines at common residential setbacks is not sufficient to cause hearing impairment or other direct health effects, although some people may find it annoying.
>
> Low frequency sound and infrasound from current generation upwind model turbines are well below the pressure sound levels at which known health effects occur. Further, there is no scientific evidence to date that vibration from low frequency wind turbine noise causes adverse health effects.

What specifically is responsible for the illness reported near wind turbines is controversial; while some of this controversy is scientifically valid, some of it is politically motivated (Phillips, 2010).

It is intriguing that not everyone in the same home experiences symptoms, and the symptoms are not necessarily worse for those nearest the turbines. Indeed, the situation may be much more complex than noise and shadow flicker.

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Why do some people who live near wind turbines become sick while others feel no ill effects? What aspects of wind power generation and distribution are responsible for the health problems? What can be done to minimize adverse human biological and health effects? These are some of the questions addressed in this report.

Wind Turbines Make Waves

What aspects of wind power generation and distribution are responsible for the adverse health effects experienced by those who live near wind turbines?

The short answer to this question is that *wind turbines make waves*. They make pressure waves and electromagnetic waves. The pressure waves (or sound waves) generated by the moving turbines can be heard as noise and/or perceived as infrasound. The electromagnetic waves are generated by the conversion of wind energy to electricity. This conversion produces high-frequency transients and harmonics that result in poor power quality. These high frequencies can flow along the wires (dirty electricity) and along the ground, thereby causing ground current. These four types of waves—noise, infrasound, dirty electricity, and ground current—and shadow flicker are each likely to contribute to ill health among those who live near wind turbines.

Characteristics of Sound Waves and Electromagnetic Waves

Sound waves are longitudinal waves that require a medium for transport. They travel at the speed of sound (340 meters/second) through air and are much slower than electromagnetic waves that travel at the speed of light (300,000,000 meters/second) and can travel through a vacuum. Both sound waves and electromagnetic waves have a frequency (cycles per second) and an intensity (amplitude of the wave).

Frequency refers to the number of waves or cycles per second and is known as pitch for sound. The A above middle C, for example, is set to a frequency of 440 cycles per second (hertz, abbreviated as Hz). The audible range for the human ear is between 20 and 20,000 Hz. Frequencies below 20 Hz are referred to as "infrasound," and, although they cannot be heard, they can still have an effect on the body. Infrasound can travel much greater distances than higher frequency sound waves and could potentially reach and affect a much larger population.

The frequencies of electromagnetic waves, generated by wind turbines, fall within two ranges of the electromagnetic spectrum: extremely low frequency (ELF), below 1,000 Hz; and the lower range (kilohertz [kHz] to megahertz [MHz]) of the radio frequency radiation (RFR) band. Electromagnetic waves can enter homes by various paths: through the air, along wires, through the ground, and via plumbing and other metal structures. Electromagnetic waves travelling across the ground contribute to ground current.

Intensity is measured by the amplitude of the wave and, for sound, is measured in decibels (dB). Vibrations with the same frequency but different amplitude will sound the same, but one will be louder than the other. The decibel scale is logarithmic. A quiet bedroom is at 25 dB, conversation is around 60 dB, a rock group is at 110 dB, and the human threshold of pain is at 140 dB.

The intensity of electromagnetic waves is measured in various ways: electric field, magnetic field, voltage, current, and power density. The biological effects of electromagnetic energy are a function of frequency, intensity, and both the manner and the duration of exposure.

Pressure Waves: Noise

Most people who live near wind turbines and complain of ill effects blame the effects on the noise generated by the turbines (Frey & Hadden, 2007).

> Everything changed . . . when the wind turbines arrived . . . approximately 700 metres away from our property . . . Within days of the windfarm coming into operation we began to hear a terrible noise . . . The noise drove us mad. Gave us headaches. Kept us awake at night. Prevented us from having windows and doors open in hot weather, and was extremely disturbing.
>
> This noise is like a washing machine that's gone wrong. It's whooshing, drumming, constant drumming, noise. It is agitating. It is frustrating. It is annoying. It wears you down. You can't sleep at night and you can't concentrate during the day . . . It just goes on and on . . . It's torture . . . [4 years later] You just don't get a full night's sleep and when you drop off it is always disturbed and only like "cat napping." You then get up, tired, agitated and depressed and it makes you short-tempered . . . Our lives are hell.

The French National Academy of Medicine (Chouard, 2006) issued a report that concludes,

> People living near the towers, the heights of which vary from 10 to 100 meters, sometimes complain of functional disturbances similar to those observed in syndromes of chronic sound trauma . . .
>
> The sounds emitted by the blades being low frequency, which therefore travel easily and vary according to the wind . . . constitute a permanent risk for the people exposed to them . . .
>
> . . . sound levels 1 km from an installation occasionally exceeded allowable limits.
>
> . . . the Academy recommends halting wind turbine construction closer than 1.5 km from residences. (Translated from French)

Noise, especially at night, has been associated with an increase in stress hormones leading to hypertension, stroke, heart failure, and immune problems. It is discussed in greater detail elsewhere in this journal.

Pressure Waves: Infrasound

Repetitive noise can be disturbing, especially at night, when sound seems amplified. However, pressure waves at levels outside the range of human hearing can also have unpleasant side effects.

In Nova Scotia, one family was unable to remain in their home and blamed their loss of sleep and headaches on vibrations from 17 turbines (Keller, 2006).

> The d'Entremont family complained of noise and low frequency vibrations in their house after the wind turbines began operation in May 2005. The inaudible noise deprived his family of sleep, gave his children and wife headaches, and "made it impossible for them to concentrate." They now live nearby; if they return to their home, the symptoms return.
>
> Natural Resources Canada, which oversees funding for wind farm projects, found no problems with low-frequency noise or infrasound. The government report concludes that the measurements:
>
> indicate sound at infrasonic frequencies below typical thresholds of perception; infrasound is not an issue. (cited in Frey & Hadden, 2007)

Gordon Whitehead, a retired audiologist with 20 years of experience at Dalhousie University in Halifax, conducted tests and found similar results but came up with a different conclusion:

> They're [Natural Resources Canada] viewing it from the standpoint of an engineer; I'm viewing it from the standpoint of an audiologist who works with ears . . . The report should read that (the sound) is well below the auditory threshold for perception. In other words, it's quiet enough that people would not be able to hear it. But that doesn't mean that people would not be able to perceive it.
>
> " . . . low-frequency noise can affect the balance system of the ear, leading to a range of symptoms including nausea, dizziness and vision problems. It's not perceptible to the ear but it is perceptible. It's perceptible to people with very sensitive balance mechanisms and that's generally people who get very easily seasick.

Resonance may explain why infrasound is harmful at low intensities. Different parts of the human body have different resonance frequencies. When the external frequency generated by a wind turbine approaches the resonance frequency of a part of the human body, that body part will preferentially absorb the energy and begin to vibrate. For example, frequencies that affect the inner ear (between 0.5 and 10 Hz) can interfere with balance, cause dizziness or vertigo, contribute to nausea, and be experienced as tinnitus or ringing in the ears. According to the International Standards Organization (ISO Standards 2631), frequencies for the eye are between 20 and 90 Hz, head 20 and 30 Hz, chest wall 50 and 100 Hz, abdomen 4 and 8 Hz, and spinal column 10 and 12 Hz. Some of the symptoms documented at infrasonic frequencies (between 4 and 20 Hz) include general feeling of discomfort, problems with breathing, abdominal and chest pain, urge to urinate, lump in throat, effect on speech, and head symptoms (Frey & Hadden, 2007).

According to a report by the U.S. Air Force, Institute for National Security Studies, acoustic infrasound can have dramatic and serious effects on human physiology (Bunker, 1997).

> Acoustic, infrasound: very low frequency sound which can travel long distances and easily penetrate most buildings and vehicles. Transmission of long wavelength sound creates biophysical effects, nausea, loss of bowels, disorientation, vomiting, potential organ damage or death may occur. Superior to ultrasound because it is "inband," meaning it does not lose its properties when it changes mediums such as air to tissue. By 1972 an infrasound generator had been built in France, which generated waves at 7Hz. When activated it made the people in range sick for hours.

In a paper known as "The Darmstadt Manifesto," published in September 1998 by the German Academic Initiative Group and endorsed by more than 100 university professors in Germany, the German experience with wind turbines is described as follows (cited in Frey & Hadden, 2007):

> More and more people are describing their lives as unbearable when they are directly exposed to the acoustic and optical effects of wind farms. There are reports of people being signed off sick and unfit for work, there is a growing number of complaints about symptoms such as pulse irregularities and states of anxiety, which are known to be from the effects of infrasound [sound frequencies below the normal audible limit].

Infrasound is influenced by topography, distance, and wind direction (Rogers, Manwell, & Wright, 2006) and differs from home to home and room to room because each room is a distinct cavity with its own resonant frequency. Whether a door is open or closed can alter the effect.

The biological effects of low-frequency noise (20-100 Hz) and infrasound (less than 20 Hz) are a function of intensity, frequency, duration of exposure, and direction of the vibration.

Wind Turbine Syndrome and Vibroacoustic Disease

Exposure to low-frequency noise and infrasound may produce a set of symptoms that include depression, irritability, aggressiveness, cognitive dysfunction, sleep disorder, fatigue, chest pain/pressure, headaches, joint pain, nausea, dizziness, vertigo, tinnitus, stress, heart palpitations, and other symptoms. Not everyone has the same sensitivity. Those who experience motion sickness (car, boat, plane), get dizzy or nauseous on carnival rides, have migraine headaches, or have eye or ear problems may be particularly susceptible to low-frequency vibrations.

Two different "diseases" have been associated with low-frequency noise exposure and infrasound. They are wind turbine syndrome—coined by Pierpont (2009) in her book by the same name—and vibroacoustic disease (VAD). VAD is a whole-body, systemic pathology characterized by the abnormal proliferation of extracellular matrices and caused by excessive exposure to low-frequency noise (Castelo Branco & Alves-Pereira, 2004). These two "diseases" differ as described by Pierpont (2009).

> Wind Turbine Syndrome, I propose, is mediated by the vestibular system—by disturbed sensory input to eyes, inner ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person's sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies.
>
> Vibroacoustic Disease, on the other hand, is hypothesized to be caused by direct tissue damage to a variety of organs, creating thickening of supporting structures and other pathological changes. The suspected agent is high amplitude (high power or intensity) low frequency noise. (p. 13)

VAD seems to be dose dependent, with symptoms becoming progressively worse with continued exposure. Three stages have been identified based on 70 aircraft technicians who, presumably, were exposed to much higher intensities of low-frequency noise than those who live near wind turbines (Castelo Branco, 1999, Castelo Branco & Alves-Pereira, 2004).

Stage 1: Mild, 1 to 4 years, slight mood swings, indigestion, heartburn, mouth/throat infections, bronchitis
Stage 2: Moderate, 4 to 10 years, depression, aggressiveness, pericardial thickening, light to moderate hearing impairment, chest pain, definite mood swings, back pain, fatigue, skin infections (fungal, viral, parasitic), inflammation of stomach lining, pain during urination, blood in urine, conjunctivitis, allergies
Stage 3: Severe, more than 10 years, myocardial infarction, stroke, malignancy, epilepsy, psychiatric disturbances, hemorrhages (nasal, digestive, conjunctive mucosa), varicose veins, hemorrhoids, duodenal ulcers, colitis, decrease in visual acuity, headaches, severe joint pain, intense muscular pain, neurological disturbances

Whatever name is given to the symptoms, the symptoms are real and can be caused by low-frequency sound waves and infrasound.

Electromagnetic Waves

One undesirable consequence of wind-generated electricity is poor power quality due to variable weather conditions, mechanical construction of the towers, and the electronic equipment used (Lobos, Rezmer, Sikorski, & Waclawek, 2008). Electricity in North America has a frequency of 60 Hz and is a sine wave when viewed on an oscilloscope (Figure 1). When a wind turbine generates electricity, the frequency must be converted to 60 Hz by power converters; that conversion generates a large spectrum of current and voltage oscillations leading to poor power quality (Lobos et al., 2008). Wind turbines can generate a wide range of frequencies—from less than 1 Hz (Lobos et al., 2008), with the majority of the frequencies in the kHz range associated with power conversion.

Dirty Electricity

High-frequency transient spikes that contribute to poor power quality, also known as dirty electricity, can flow along wires, damage sensitive electronic equipment, and adversely affect human and animal health.

After wind turbines were activated in Ripley, Ontario, several of the residents complained of ill health. Residents suffered from headaches, poor sleep, elevated blood pressure (requiring medication), heart palpitations, itching, ringing and pain in the ears, watering eyes, and pressure on the chest causing difficulty breathing. These symptoms disappear when the residents leave the area. Some residents were forced to move out of their homes because the symptoms were so severe. Locals complain of headaches and poor radio reception when they drive near these power lines.

One of the authors (DC) measured the power quality near several residences where people were unwell. The primary neutral-to-earth voltage (PNEV) is the electrical potential difference between the earth and the neutral wire on the primary distribution line, as shown in Figure 2. Measurements taken before wind turbines were installed and after they were installed and operating (Figure 3) clearly show the distortion (spikes on the waveform) generated by the wind turbines.

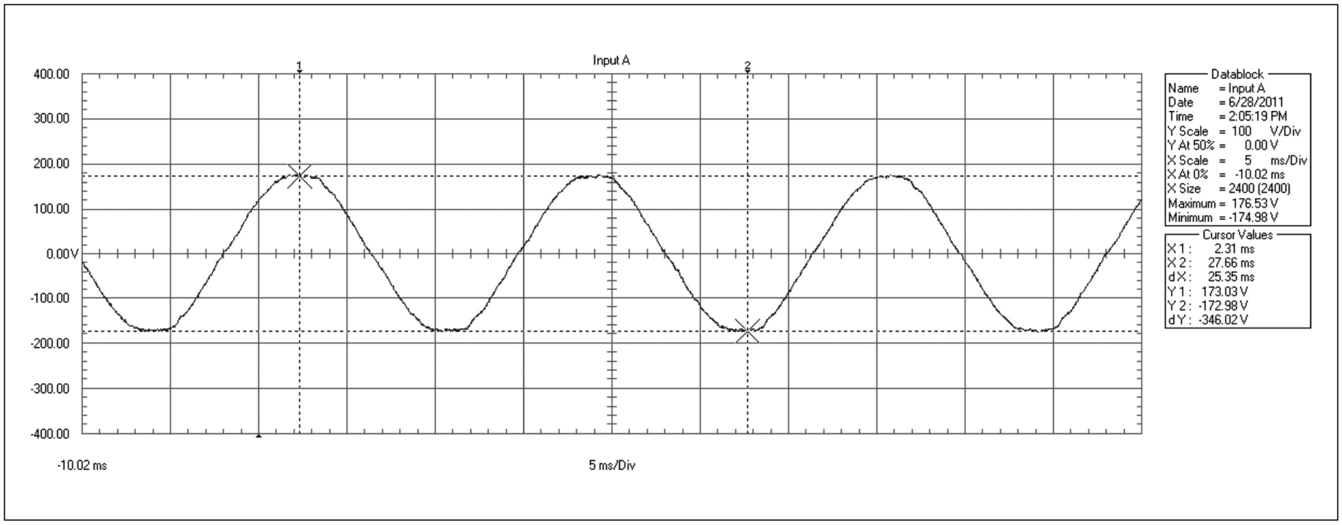

Figure 1. Good power quality exemplified by the 60-Hz sine wave

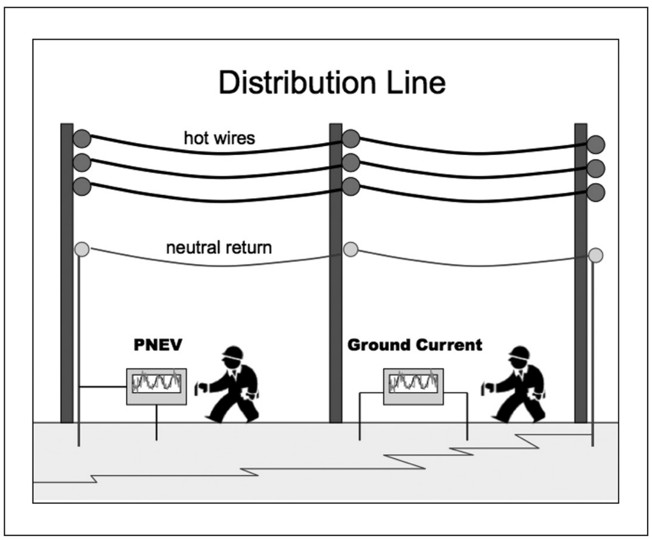

Figure 2. Diagram demonstrating how primary neutral-to-earth voltage (PNEV) and ground voltage measurements are taken

In this area, wind turbines are variable speed and are interconnected. The collection lines connecting the wind turbines to the substation are attached to the same utility pole as the home owners' lines.

According to one of the authors (DC; September 30, 2008),

> We had four families move out of their homes and now if I spend too much time in these homes I get the same symptoms, which is ear aches, ringing in the ears and pressure in the ears. [name removed] eventually buried a portion of the line but have only isolated the lines by insulators so it is better, however there is still some high frequency coming into the houses. The three families that now have buried lines are back in their homes, but things are far from ideal.

Dirty electricity in the kHz range affects human health; this has been shown in schools and homes in both Canada and the United States. Power quality can be improved both on electrical wires by using power line filters (Ontario Hydro, 1998) and inside buildings by using special surge suppressors or power filters that dampen the voltage spikes (http://www.stetzerelectric.com).

In one Wisconsin School that had "sick building syndrome," once power quality was improved, the health of both teachers' and students' improved. According to the school nurse, both staff and students have more energy, fewer allergies, and fewer migraine headaches, and asthmatics rely less on their inhalers (Havas, 2006a).

In a Toronto School, improvements in power quality were accompanied by improvements in teachers' health and students' behavior. Teachers were less tired, less frustrated, less irritable; they had better health and more energy; they had a greater sense of satisfaction and accomplishment; they were more focused and experienced less pain. Students' behavior also improved especially in the elementary grades (Havas, Illiatovitch, & Proctor, 2004). Similar results were reported in a placebo-blinded study in three Minnesota schools (Havas & Olstad, 2008).

Dirty electricity has been associated with increased risk of various types of cancers among teachers in a California school (Milham & Morgan, 2008), with higher blood sugar levels among diabetics, and with exacerbation of tremors and difficulty walking among those with multiple sclerosis (Havas, 2006b). People who are adversely affected by dirty electricity are classified as electrically hypersensitive.

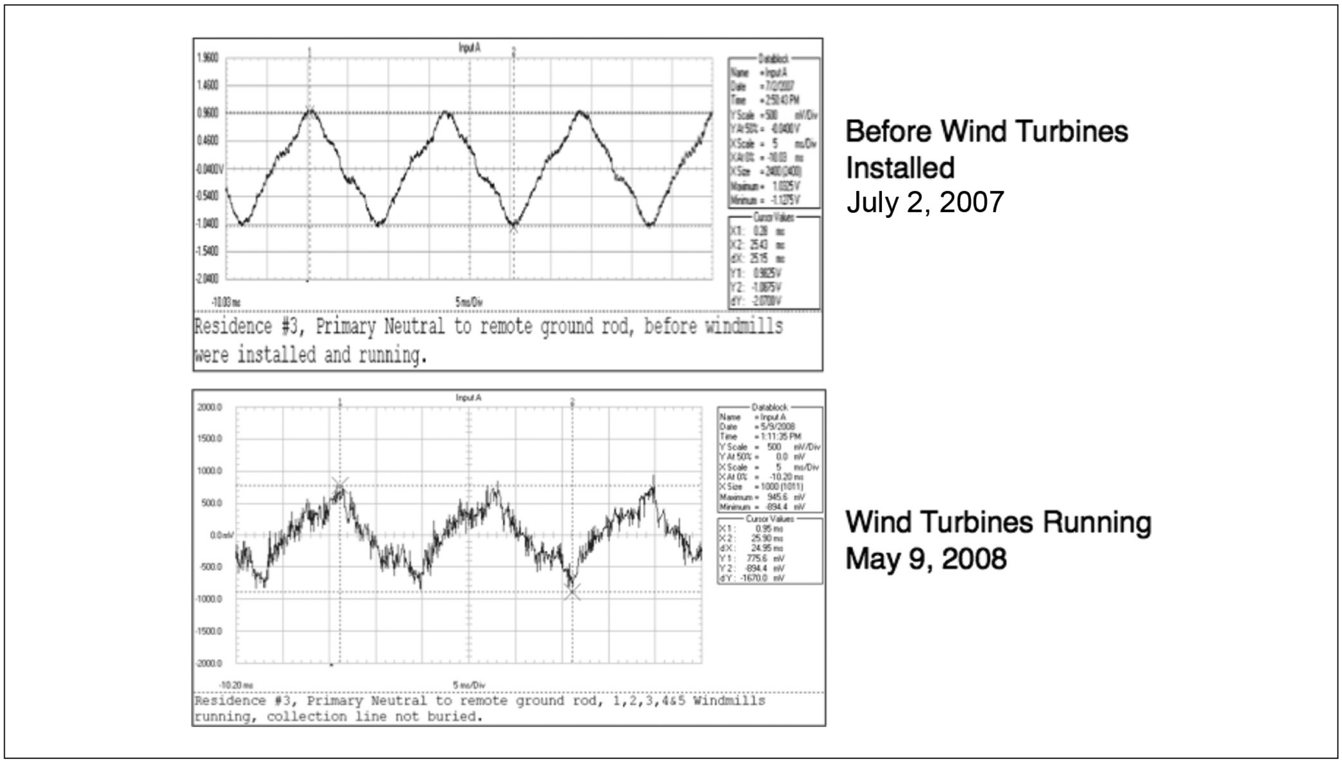

Figure 3. Primary neutral-to-earth voltage (PNEV) at Residence No. 3 in Ripley, Ontario, before wind turbines were installed (July 2, 2007) and when five wind turbines were operating (May 9, 2008)
Note. Collection line was not buried.

Ground Current

Just as dirty electricity can flow along wires, it can also flow along the ground resulting in ground current. Ground current (often measured as voltage and called stray voltage or tingle voltage) is a serious problem in certain locations and has been shown to adversely affect the health of farm families and the health and productivity of farm animals, especially dairy cattle.

The Ontario Federation of Agriculture (2007) provides information on symptoms experienced by farm animals, pets, and people who are exposed to tingle voltage as follows:

> Farmers and their families who suffer from immune disorders such as allergies or rheumatoid arthritis find their symptoms worsen or go into remission in close coordination with livestock symptoms. Periods of fatigue increase. Sleep disorders may increase.
>
> Cats leave the farm, become ill, cease to bear litters or have small, unhealthy litters, or die; coats are usually dull and shaggy and eyes are runny.
>
> Horses may paw the ground and shy away from watering or feeding troughs; behaviour and handling becomes more difficult.
>
> Pigs often take to ear and tail biting; mastitis and baby pig scours are common; piglet mortality may increase.
>
> Cattle lap water from the trough or bowl; feed in the bottom of the manger is not cleaned up; milk out is slow and uneven; cows are reluctant to enter the milk parlour and quick to leave; slow growth in calves and heifers; somatic cell counts are high; unexplained spontaneous abortions of calves; bulls become markedly more irritable.

According to the *National Electrical Safety Code (NESC) Handbook* (Clapp, 1997),

> When the earth returns were used in some rural areas prior to the 1960's, they became notorious offenders in dairy areas because circulating currents often cause both step and touch potentials.
>
> In some cases, they have adversely affected milking operations by shocking the cattle when they were connected to the milking machines, and have affected feeding. (p. 152)

According to Lefcourt (1991) in the U.S. Department of Agriculture book titled *Effects of Electrical Voltage/Current on Farm Animals: How to Detect and Remedy Problems*:

> The effect of a transient voltage superimposed on the regular power voltage (dc or ac) is to cause a momentary

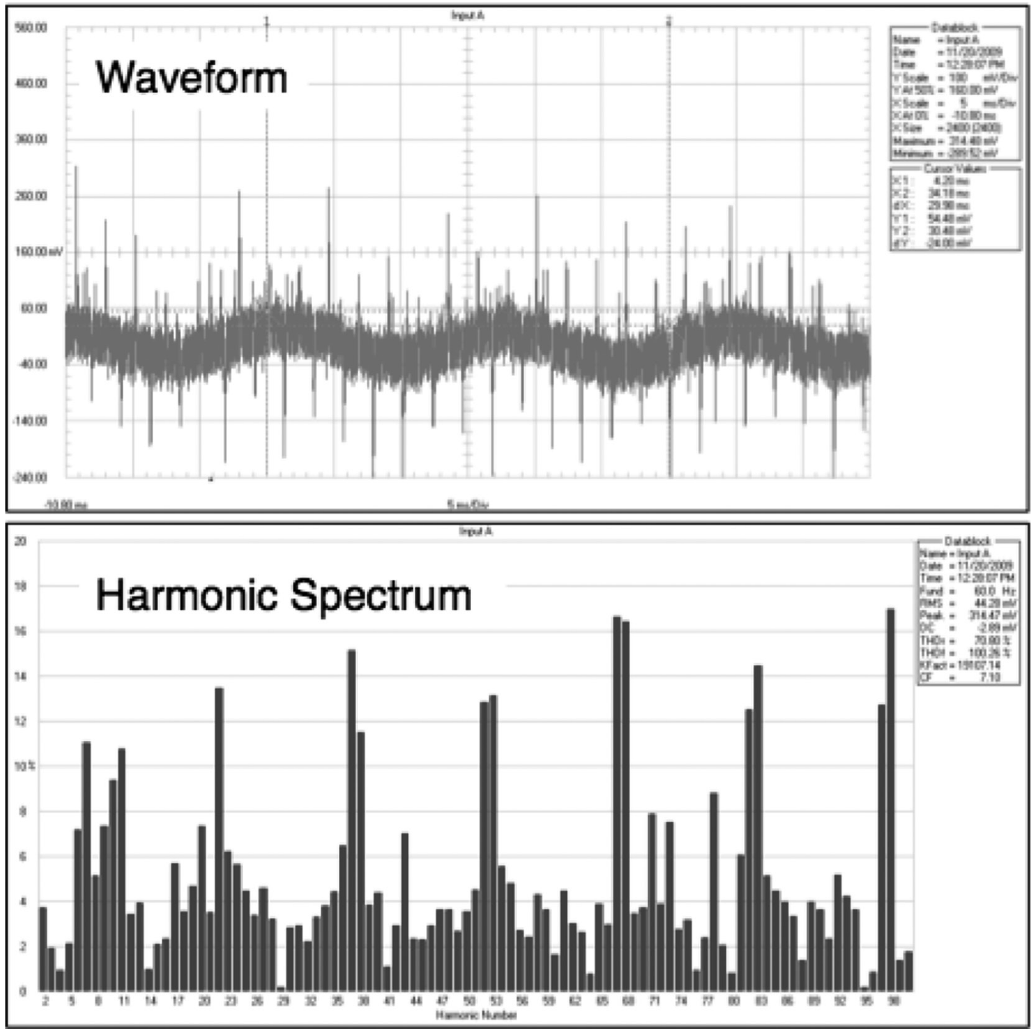

Figure 4. Ground voltage measured at the Palm Springs wind farm in California using 50 feet of copper wire attached to two metal rods in the earth

Note. The top graph shows the distorted 60-Hz waveform, and the bottom graph shows the harmonic frequencies. Data courtesy of Dr. Sam Milham.

> change in the waveform. When the transient causes the momentary voltage to be greater than normal, it may cause a transient current to flow in an animal. If the transient waveform has sufficient energy (magnitude and duration), there may be an animal response. (p. 63-64)

Indeed, dirty electricity flowing along the ground may be more harmful to farm animals than the 60-Hz ground current (Hillman et al., 2003):

> Cows were sensitive to harmonic distortions of step-potential voltage, suggesting that utility compliance with IEEE standards on dairy farms may need to be addressed.
>
> Power quality varied greatly from farm to farm and day to day. Milk production responses to changes in power quality varied inversely with the number of transient events recorded with event recorders, oscilloscope, and power quality meters. Harmonics often gave better estimates of electrical effects on milk production than voltage *per se*. (p. 19)

Do wind turbines generate ground current? They can if proper safeguards are not taken. Generally, this is a problem with power distribution once the energy leaves the turbine.

Figure 4 shows the waveform of ground voltage near an industrial wind farm in Palm Springs, California (as shown in Figure 5 photographs). The waveform distortion in Figure 3 and 4 are considerable when compared with Figure 1.

Figure 5. Wind farm in Palm Springs, California, showing (A) location of ground voltage readings; (B), view of wind turbines from the ground; and (C) view of wind turbines from the air
Note. Photograph A from Dr. Sam Milham. Photographs B and C from Google maps.

Burying the collection line may not eliminate the ground voltage but can improve power quality, as shown in Figure 6.

Just as animals are adversely affected by dirty ground current, so are people. If ground current enters a home via the plumbing, touching any part of the plumbing (e.g., faucet) induces a current in the body, known as contact current.

In one Ripley home, the frequency fingerprint (relative intensities of various frequencies) on the plumbing (sink to floor measurement) was similar to the PNEV, indicating that the source of the ground voltage was the wind turbines' collection line (Figure 7). In this home, the sink to floor contact current was calculated to be 400 microamperes (peak to peak based on 200 millivolts and 500 ohms), and this value is 22 times higher than levels associated with cancer according to Kavet, Zaffanella, Daigle, and Ebi (2000).

> "The absolute (as well as modest) level of contact current modeled (18 micro Amps) produces average electric fields in tissue along its path that exceed 1 mV/m. At and above this level, the NIEHS Working Group [1998] accepts that biological effects relevant to cancer have been reported in "numerous well-programmed studies." (p. 547)

Wertheimer, Savitz, and Leeper (1995) documented the link between ground current and cancer in Denver, Colorado. They found that leukemia risk increased by 300% among children exposed to elevated magnetic field from ground current that enters the home through conductive plumbing.

Electrohypersensitivity (EHS)

Why do some people who live near wind turbines become sick while others feel no ill effects?

Exposure to both pressure waves and electromagnetic waves is highly variable—spatially and temporally—as is sensitivity to these vibrations. Not everyone in the same home is going to have the same exposure or the same sensitivity. People who have balance problems, experience motion sickness, or have ear or eye problems are more likely to react to low-frequency sound vibrations. Those who are electrically hypersensitive are more likely to suffer from dirty electricity

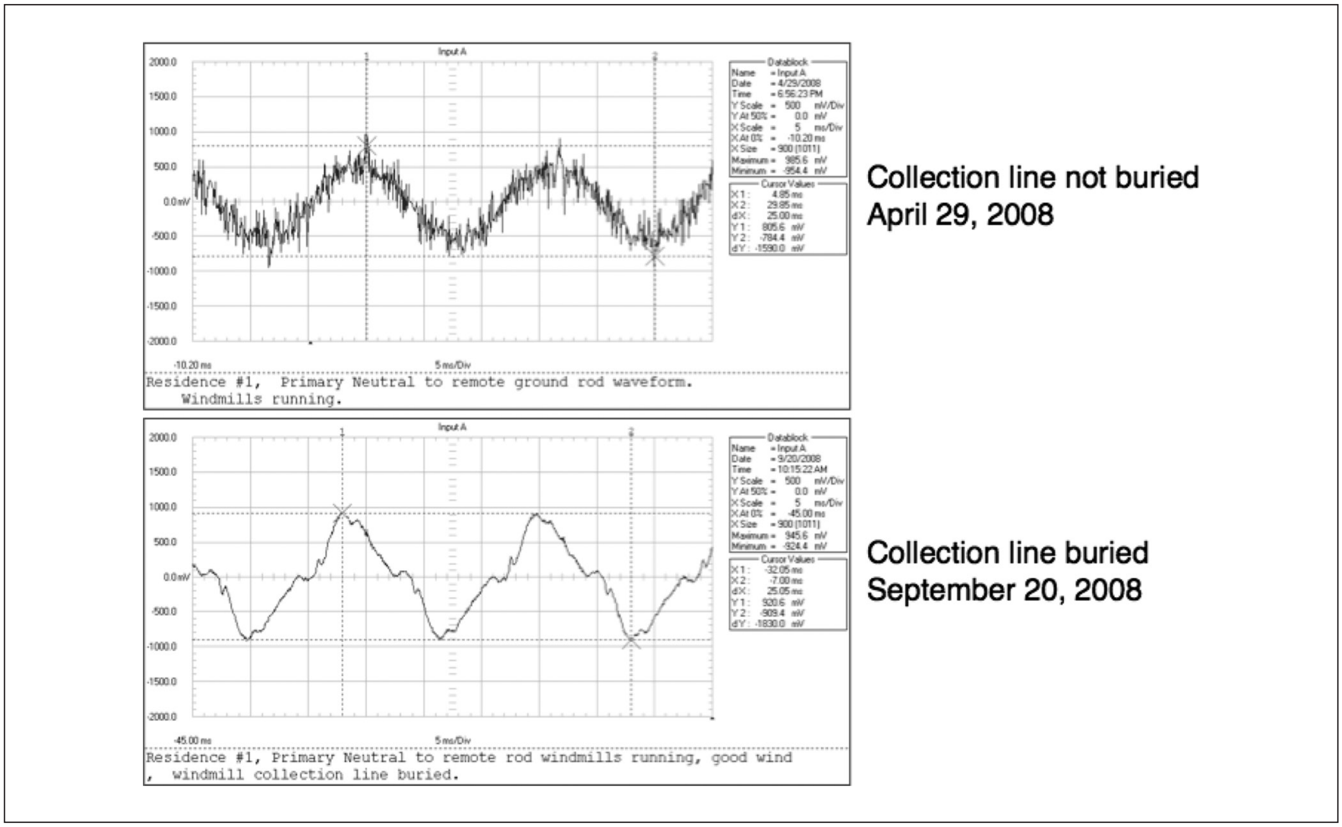

Figure 6. Primary neutral-to-earth voltage (PNEV) at Residence 1 in Ripley, Ontario, when wind turbines were operating
Note. Collection line from wind turbines was buried on September 20, 2008 (bottom graph), but not on April 29, 2008 (top graph).

and contact current. As a result, people living in the same home may have very different sensitivities and may respond differently to these vibrations.

At the Working Group meeting on EMF Hypersensitivity in Prague, the World Health Organization (2004) described electrosensitivity as

> a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic, or electromagnetic fields (EMFs).
>
> Whatever its cause, EHS is a real and sometimes a debilitating problem for the affected persons, while the level of EMF in their neighborhood is no greater than is encountered in normal living environments. Their exposures are generally several orders of magnitude under the limits in internationally accepted standards.

Symptoms include cognitive dysfunction (memory, concentration, problem solving); fatigue and poor sleep; body aches and headaches; mood disorders (depression, anxiety, irritability, frustration, temper); nausea; problems with balance, dizziness, and vertigo; facial flushing, skin irritations, and skin rashes; chest pressure, rapid heart rate, and altered blood pressure; ringing in the ear (tinnitus); and nosebleeds. A comprehensive list of the symptoms is provided in Table 1.

In Sweden, EHS is recognized as a functional impairment (not as a disease). Between 230,000 and 290,000 Swedes (about 3% of the Swedish population) may be electrohypersensitive (Johansson, 2006). The number of people complaining of EHS seems to be increasing as is the medication sold to deal with the symptoms of insomnia, pain, fatigue, depression, and anxiety. By 2017, as many as 50% of the population may experience these symptoms (Hallberg & Oberfeld, 2006).

Some individuals may have a predisposition to EHS. Those who have experienced physical trauma to their nervous system (whiplash), electrical trauma in the form of multiple shocks or several severe shocks, and/or chemical exposure to mercury or pesticides are likely to be more electrically sensitive. Children, the elderly, and those with impaired immune systems are also likely to be more electrically sensitive.

It is not possible to determine which factors are contributing to ill health until appropriate monitoring is conducted and steps are taken to reduce exposure to the offending agents. Monitoring of both electromagnetic waves and pressure waves in homes where people report ill health is highly recommended as are the mitigation techniques mentioned below

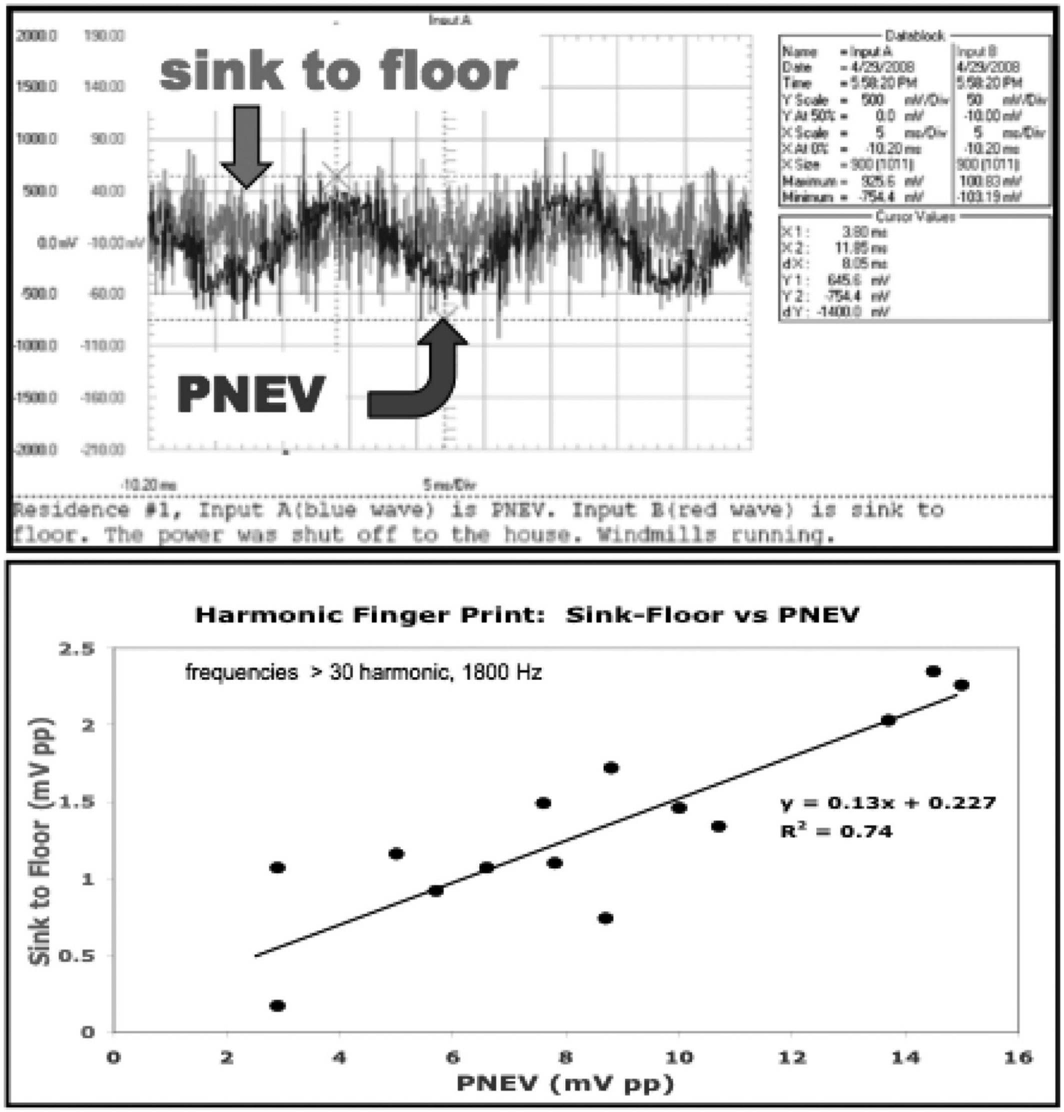

Figure 7. The primary neutral-to-earth voltage (PNEV) and the sink-to-floor voltage for Residence 1 in Ripley, Ontario (top graph), and the harmonic figure print for these voltages (bottom graph).

Recommendations

What can be done to minimize adverse biological and health effects for those living near wind turbines?

One obvious step is to eliminate or reduce exposure to the agent(s) causing the illness.

1. To minimize noise and exposure to infrasound, the following steps should be taken:
   a. Wind turbines should be placed as far away as possible from residential areas. The French National Academy of Medicine (Chouard, 2006) recommends 1.5 km from residential areas.
   b. Buffers can be constructed to disrupt pressure waves and to absorb or deflect sound waves in areas where turbines are closer to homes or where problems have been documented,
2. To improve power quality, the following steps should be taken:
   a. The electricity should be "filtered" at all inverters before it leaves the wind turbine. Ontario Hydro (1998) provides information on power line filters and other ways to improve power quality.
   b. The collector lines from the wind turbines should be attached to utility poles that do not provide power to homes.
   c. Power from the substation supplied by the wind turbines should be filtered before it is distributed to customers.

Table 1. Comprehensive List of Electrohypersensitivity (EHS) Symptoms (Bevington, 2010)

Auditory	**Dermatological**	**Musculoskeletal**	**Ophthalmologic**
earaches,	brown 'sun spots',	aches / numbness	eyelid tremors/'tics',
imbalance,	crawling sensations,	pain / prickling	impaired vision,
lowered auditory	dry skin,	sensations in:	irritating sensation,
threshold,	facial flushing,	bones, joints &	pain / 'gritty' feeling,
tinnitus	growths & lumps,	muscles in:	pressure behind eyes,
	insect bites & stings,	ankles, arms, feet	shiny eyes,
Cardiovascular	severe acne,	legs, neck,	smarting, dry eyes
altered heart rate,	skin irritation,	shoulders, wrists,	
chest pains,	skin rashes,	elbows, pelvis,	**Other**
cold extremities	skin tingling,	hips, lower back,	**Physiological**
especially hands	swelling of face/neck	cramp / tension in:	abnormal
& feet,		arms, legs, toes,	menstruation,
heart arrhythmias,	**Emotional**	muscle spasms,	brittle nails,
internal bleeding,	anger,	muscular paralysis,	hair loss,
lowered/raised	anxiety attacks,	muscular weakness,	itchy scalp,
blood pressure,	crying,	pain in lips, jaws,	metal redistribution,
nosebleeds,	depression,	teeth with amalgam	thirst / dryness of
shortness of breath,	feeling out of control,	fillings,	lips, tongue, eyes
thrombosis effects	irritability,	restless legs,	
	logorrhoea,	tremor & shaking	**Respiratory**
Cognitive	mood swings,		asthma,
confusion,		**Neurological**	bronchitis,
difficulty in learning	**Gastrointestinal**	faintness, dizziness,	cough /throat irritation,
new things,	altered appetite,	'flu-like symptoms,	pneumonia,
lack of concentration,	digestive problems,	headaches,	sinusitis
short / long-term	flatulence,	hyperactivity,	
memory impairment,	food intolerances	nausea,	**Sensitisation**
spatial disorientation		numbness,	allergies,
	Genito-urinary	sleep problems,	chemical sensitivity,
	smelly sweat / urine,	tiredness	light sensitivity,
	urinary urgency,		noise sensitivity,
	bowel urgency		smell sensitivity

   d. Wind power electrical substations that require power from an external source (electrical distribution network) must ensure that the power quality of this eternal source is not affected as this can result in power quality problems for customers connected to the same external power source.
   e. Nearby home owners may need to install power line filters in their homes if levels of dirty electricity remain high.
3. To reduce ground current/voltage, the following steps should be taken:
   a A proper neutral system (possibly a five-wire system) should be installed to handle the high-frequency return current in overhead lines (Electric Power Research Institute, 1995).
   b. Insulators can be placed between the neutral line and the grounding grid for the wind turbine.
   c. The collection lines from the wind turbine to the substation should be buried if the other techniques to minimize dirty ground current are ineffective.
   d. Local home owners may need to install stray voltage isolators near their transformers until the electric utility can resolve the problem (Hydro One, 2007).

If these steps are taken, improved quality of life and a feeling of wellness may return to some of the people adversely affected by nearby wind turbines.

Conclusions

A subset of the population living near wind turbines is experiencing symptoms of ill health. These symptoms are likely caused by a combination of noise, infrasound, dirty electricity, ground current, and shadow flicker. These frequencies can be highly viable spatially and temporally and are affected by distance; terrain; wind speed and direction; shape, size, and type of dwelling; type of power converters used; state of the electrical distribution line; type and number of grounding systems; and even the type of plumbing in homes. Furthermore, not everyone has the same sensitivity to sound and electromagnetic radiation nor do they have the same symptoms. The following symptoms seem to be quite common: sleeplessness, fatigue, pain, dizziness, nausea, mood disorders, cognitive difficulties, skin irritations, and tinnitus. To help alleviate symptoms in areas where wind turbines have been erected, remediation is necessary to reduce or eliminate both sound waves and electromagnetic waves. More research is required to help us better understand the relative importance of the various factors contributing to poor health. This type of information will enable a healthy coexistence between wind turbines and the people living nearby.

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Industrial Wind Turbine Development and Loss of Social Justice?

Carmen M. E. Krogh[1]

Abstract

This article explores the loss of social justice reported by individuals living in the environs of industrial wind turbines (IWTs). References indicate that some individuals residing in proximity to IWT facilities experience adverse health effects. These adverse health effects are severe enough that some families have abandoned their homes. Individuals report they welcomed IWTs into their community and the negative consequences were unexpected. Expressions of grief are exacerbated by the emotional and physical toll of individuals' symptoms, loss of enjoyment of homes and property, disturbed living conditions, financial loss, and the lack of society's recognition of their situation. The author has investigated the reported loss of social justice through a review of literature, personal interviews with, and communications from, those reporting adverse health effects. The author's intention is to create awareness that loss of social justice is being associated with IWT development. This loss of justice arises from a number of factors, including the lack of fair process, the loss of rights, and associated disempowerment. These societal themes require further investigation. Research by health professionals and social scientists is urgently needed to address the health and social impacts of IWTs operating near family homes.

Keywords

wind turbines, adverse health effects, social justice, procedural justice, disempowerment, disturbed living conditions, impact statements, loss of home, societal themes

Introduction

It is recognized that there are many elements which define human health:

> At the Ottawa Conference in 1986, the World Health Organization, along with Health Canada (formerly Health and Welfare Canada) and the Canadian Public Health Association, agreed on the Ottawa Charter for Health Promotion. The Charter sees health in the context of the interaction between the person and the environment. It recognizes the elements of our social environment, including peace, shelter, education, food, income, social justice and equity as prerequisites for health. (Health Canada, 2004, vol. 1, p. 15)

Many articles regarding social justice are available in a variety of psychology and sociology journals and on the Internet; however, a simple definition of social justice seems elusive.

Shain (2011) in a communication with the author comments,

> While there is no one account of procedural justice upon which there is consensus, the criteria for what constitutes a fair procedure advanced by Leventhal (1980) enjoy considerable support and have been used in numerous research studies on the subject (Tyler, Boeckmann, Smith, & Huo, 1997).
>
> Leventhal (1980) proposes six key criteria that people use wittingly or otherwise in judging to what extent a decision-making procedure or process is just or fair:
>
> - *Consistency:* Equal treatment of persons across time and place
> - *Bias suppression:* Avoiding self-interest or ideological preconceptions
> - *Accuracy:* Using good, accurate information and informed opinions
> - *Correctability:* Opportunities for review and amendment
> - *Representativeness:* Everyone is involved in decision making who has a material interest in the outcome

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- *Ethicality:* Compatible with fundamental moral and ethical values

These criteria collectively amount to a definition of fair process.

As such, they resonate with Trebilcock's (1993) analysis of what causes breakdowns in contractual relationships: information failure and participation failure. And at a more philosophical level, they resonate with a working definition of fairness given by Shain (2001) following Rawls (2001) in his seminal treatise on *Justice as Fairness* (see also Rawls, 1971).

This definition sees fairness as "the recognition and reasonable accommodation of one another's legitimate interests, claims and rights." As such, fairness calls for a process in which people who are brought into relationships with one another are actively enjoined to make themselves aware of one another's interests, claims, and rights, to understand these as best they can, and to use their knowledge to arrive at best-fit solutions that accommodate all involved. This imperative applies not only to parties involved in personal and domestic relationships but also to those involved in community and commercial undertakings.

While this is a tall order, it is nonetheless the goal of procedural fairness. It also describes the antithesis of the situation we confront in connection with the licensing and siting of industrial wind turbines (IWTs).

These concepts set the stage to raise awareness of the issues associated with social justice and its effects on those living in the environs of IWTs.

Urgent research by health professionals and social scientists is required to further study this social phenomenon.

The Beginning

In January 2009, I began investigating reports of adverse health effects made by individuals living in the environs of IWTs. Over the course of more than 2 years I have been in communication with many of those experiencing physiological and psychological symptoms in Ontario, Canada and elsewhere globally. The descriptions of reported symptoms are consistent and based on individuals' reports, correlate with the onset of IWT facilities' operations.

An impact statement from early 2009 provoked my awareness that in addition to experiencing adverse health effects, there was evidence of a feeling of disempowerment and lack of process: "I trusted the wind energy companies"—"I can't believe the government is doing this to me." (S. M., personal communications, 2009, Ontario).

Many feel abandoned by the very procedural systems they believed would protect them. Through my research, I observed a progression of impacts starting with the identification of physiological and psychological symptoms and culminating with frustration, grief and anger, disempowerment, loss of trust, and an overall sense of social injustice.

When the health symptoms became apparent, there was an expectation that authorities and/or the IWT developer would resolve the issues. Individuals report their distress intensified when attempts to obtain recognition of their situation failed. An unexpected lack of response from a cross section of society, including government officials, industry, medical practitioners led to an exacerbation of their situation.

Failure to obtain recognition and resolution has resulted in some individuals seeking legal counsel, abandoning their home, or continuing to experience the adverse health effects, which ultimately, heightens the feelings of injustice.

Social well-being is acknowledged to be a determinant of health: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization [WHO], 1948). Many jurisdictions, including the Canadian federal, provincial, and territorial governments and health officials have accepted WHO's definition of health (Health Canada, 2004, vol. 1, p. 1-1).

Social Justice Violated

The WHO (2008) acknowledges the importance of social justice. It states, "Social justice is a matter of life and death. It affects the way people live, their consequent chance of illness, and their risk of premature death" (p. 3).

This statement set the stage for my presentation on social justice and IWTs (Krogh, 2010) given during the Society for Wind Vigilance, First International Symposium "The Global Wind Industry and Adverse Health Effects: Loss of Social Justice?"

The WHO (2008) final report on social determinants of health identifies three overarching principles:

1. Improve daily living conditions.
2. Tackle the inequitable distribution of power, money, and resources.
3. Measure and understand the problem and assess the impact of action.

Improve Daily Living Conditions

WHO (2008) states, "Different government policies, depending on their nature, can either improve or worsen health and health equity" (p. 110).

In response to environmental and economic concerns, some governments have adopted wind energy development as an alternative energy source (Green Energy and Economy Act, 2009; VisitDenmark, 2009). In some jurisdictions, implementation of IWTs has resulted in unexpected consequences. There are global reports of adverse health effects correlated with the onset of operations of IWTs (Harry, 2007; Krogh, Gillis, & Kouwen, 2011; Nissenbaum, 2009; Pierpont, 2009; Phipps, Amati, McCoard, & Fisher, 2007).

In several case series, respondents report experiencing a reduced quality of life. WindVOiCe, a self-reporting health survey from Ontario, Canada found that in addition to a plethora of symptoms, 113 of 131 respondents reported altered quality of life (Krogh et al., 2011). Similarly, in the United Kingdom, Harry (2007), 40 of 42 reported this as well.

In my presentation at the Society for Wind Vigilance International Symposium held in Ontario, Canada, I presented impact statements from a number of countries that described disturbed living conditions and adverse health effects (Krogh, 2010). One impact statement from Japan described how family members were sufficiently sleep disturbed by IWT noise they resorted to renting a second home in order to sleep. A family member from Germany described experiencing tachycardia, which intensified as the IWT speed increased.

References, both from peer-reviewed and other literature, acknowledge that IWTs may cause annoyance and/or stress and/or sleep disturbance (Colby et al., 2009; Keith, Michaud, & Bly, 2008; Minnesota Department of Health, 2009; Pedersen & Persson Waye, 2004, 2007; Rideout, Copes, & Bos, 2010; Thorne, 2010).

The Wind Turbine Noise (2011) post–conference report states,

> The main effect of daytime wind turbine noise is annoyance. The night time effect is sleep disturbance. These may lead to stress related illness in some people. Work is required in understanding why low levels of wind turbine noise may produce affects which are greater than might be expected from their levels.

Noise from IWTs is found to be more annoying than other sources of noise at comparable sound pressure levels (Pedersen, Bakker, Bouma, & van den Berg, 2009).

In everyday language, the term *annoyance* may be viewed by some as trivial; however, in the context of human health, annoyance is an adverse health effect (Health Canada, 2005). In 1991, Suter commented that

> “Annoyance” has been the term used to describe the community’s collective feelings about noise ever since the early noise surveys in the 1950s and 1960s, although some have suggested that this term tends to minimize the impact. While “aversion” or “distress” might be more appropriate descriptors, their use would make comparisons to previous research difficult. It should be clear, however, that annoyance can connote more than a slight irritation; it can mean a significant degradation in the quality of life. This represents a degradation of health in accordance with the WHO’s definition of health, meaning total physical and mental well-being, as well as the absence of disease. (p. 27)

Niemann and Maschke (2004) also comment on the significance of annoyance: “The result confirms the thesis that for chronically strong annoyance a causal chain exists between the three steps health–strong annoyance–increased morbidity” (p. 18).

The exact cause of IWT-induced adverse health effects is not fully understood. Plausible causes are not limited to but include amplitude modulation, temporal variability, lack of nighttime abatement, shadow flicker, and visual impact. Audible low-frequency noise has also been identified as one of the IWT noise characteristics that can be a contributing factor for annoyance (Minnesota Department of Health, 2009; Møller & Pedersen, 2010).

Reported symptoms associated with human exposure to IWT’s include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering when awake or asleep (Pierpont, 2009, p. 26).

Leventhall (2009) attributes these reported IWT symptoms as effects of “annoyance by noise” stating, “I am happy to accept these symptoms, as they have been known to me for many years as the symptoms of extreme psychological stress from environmental noise, particularly low frequency noise.”

The effects of low-frequency noise–induced annoyance and stress from various sources have been researched. “Regulatory authorities must accept that annoyance by low frequency noise presents a real problem . . .” and that “The claim that their ‘lives have been ruined’ by the noise is not an exaggeration . . .” (Leventhall, 2004).

DeGagne and Lapka (2008) note, “Unlike higher frequency noise issues, LFN is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes makes it worse . . .”

Respite from the effects of low-frequency noise can require extreme measures: “Those exposed may adopt protective strategies, such as sleeping in their garage if the noise is less disturbing there. Or they may sleep elsewhere, returning to their own homes only during the day” (Leventhall, 2004).

In Ontario, personal communications with individuals residing in the environs of IWTs report their attempts to mitigate the low-frequency component of the noise by wearing ear protection day and night proved to be ineffective. To escape the noise, some report resorting to sleeping in vehicles, tents, trailers, basements lined with mattresses, garages, and at relatives or friends’ homes. Others have bought or rented a second residence to obtain respite (G. W., personal communications, 2010; T. W., personal communications, 2011) or relocated with friends or family (T. K., personal communications, 2011). Some families have been billeted at the IWT developer’s expense (Hansard, 2009, p. G-547). Others have abandoned their homes or been bought out by wind developers (Braithwaite, 2009a, 2009b). Buyouts by IWT developers have been reported in other parts of the globe (Rolfe, 2011).

An impact statement from Italy conveys the health and economic effects associated with having to leave their home:

". . . I had to abandon my home . . . because of the terrible symptoms. My house is worth nothing." (G. A., personal communications, 2010).

An individual representing a group of families testified before the Ontario Standing Committee on Green Energy and Green Economy Act and described how

> Each family has incurred additional costs from budgets for food, fuel, laundry and doctor visits while living away from our homes. Family events had to be held in restaurants. There is wear and tear on our vehicles. There is the extra cost of extensive phone bills from trying to get the problems fixed. There is the price of putting isolators on our homes to protect our families from the unfiltered power. There's the cost of going to meetings. There's loss of productivity due to sleep deprivation. A loss of three weeks from work occurred.
>
> Ontario common law and MLS rules and regulations set out for Ontario realtors all require full disclosure of factual information regarding properties offered for sale by owners. This means an owner is legally obligated to disclose any information known or expected about a property that may affect a buyer's decision to purchase a property.
>
> My real estate agent tells me our farm is unsellable. Our homes are unsellable or of zero value. Buying a second home to live in, which I've done—possible lawyer fees, possible appraisal costs. Our lives are upside down for the last 18 months, and how do you put a cost on that? This is like someone committing a crime, going to jail for, say, 10 years and then finding out after DNA tests, "Oh, you're innocent." How do you get that time back at our ages? (Hansard, 2009, p. G-548)

P. C. from Ontario described the impacts to the family:

> Although we did not realize it at the time, November, 2008 was to be the beginning of the worst nightmare to affect our quality of life that we had and still have ever experienced. There was now a total of 33 industrial wind turbines within a 3 km radius of our house. With the whirling of the turbines came the destruction of personal, family and social life as we knew it. I was positive that the wind corporation and our government would fix the problem as soon as I told them that the noise of the turbines was affecting our health and our quality of life. I was wrong! Since May, 2009 I have been communicating with the wind corporation and with various ministries of our Ontario government (mostly MOE) explaining that the noise from the turbines often makes it impossible to sleep thus causing other health problems that are associated with lack of sleep and sleep disturbance. We also started often feeling our bed vibrate, our chest vibrate, our heart racing, headaches, nausea, pounding in the ears. We were told that mitigations are in place, we are still feeling the same ill effects (P. C., personal communications, 2011).

The impacts on P.C.'s family life have extended to an elderly mother who had to leave the affected home and adult children who were unable to visit:

> Our lives have been changed drastically . . . have been ruined. The building we live in is not a home because the 33 turbines within a 3 km radius have an adverse effect on the health of the people who live in this house and the turbines cause a loss of enjoyment of normal use of our property. The whooshing audible noise of the turbines is torture, it is often a continuous "on/off" whooshing noise often both inside and outside our house. In my opinion, our government pretends we do not exist. Our government caused this problem, we did not ask for it yet we suffer. We are moms, dads, grandpas, grandmas, children, babies, pregnant mothers . . . why have we become insignificant to the turbine corporations and to our provincial government? (P. C., personal communications, 2011)

Additional testimony has described negative health and societal impacts:

> We are quizzed or defending our health problems at community events such as hockey games, shopping or church. Dysfunctional community relations have been created by the wind project representatives and some community members trying to discredit the validity of our problems.
>
> The family unit for each family has deteriorated and has been torn apart. We begged for sleep, and four families were billeted by the wind company from their homes for 90 to 180 days in motels, hotels and a rooming house. The consistent stress has broken apart the family unit—no gatherings, few or no celebrations at home. At present, one family has purchased a separate residence to live in, and two others had to, at the expense of thousands of dollars, modify their hydro connection to try and live in their homes that they've lived in for 19 to 35 years.
>
> Due to concerns for the health of grandchildren, grandparents, older children, extended family members and friends, we all strongly discourage extended visits to our homes. We had to meet somewhere else other than our homes for celebrations. (Hansard, 2009, p. G-547)

While the data base of youth impact statements is limited, some young people are also negatively affected. A teenager reports having to leave home prematurely. This displacement and separation of family was destructive. The outcome is isolation from friends and family: "I am forced to sit back and say nothing as my own teachers teaches my classmates and peers that wind energy is flawless . . . I am forced to live away from home with my grandmother . . . I can never go home" (J. K., personal communications, 2010).

Tackle the Inequitable Distribution of Power, Money, and Resources

WHO (2008) states, "Empower all groups in society through fair representation in decision-making about how society operates, particularly in relation to its effect on health equity, and create and maintain a socially inclusive framework for policy-making" (p. 158).

Absence of fairness has been raised globally by individuals who are disturbed by some governments' procedures for implementing a renewable energy policy. Rapid introduction of IWTs into rural communities has resulted in negative social impacts.

For example, in Ontario, the Green Energy and Economy Act (2009) was passed with the intention of streamlining the approval process for thousands of IWTs. The Act legislated a centralized decision-making process and removed jurisdictional authority from local municipalities (Gallant, 2011). The domino effect is that those living in the affected communities are unable to participate in meaningful consultation.

In Ontario, local communities no longer have planning authority to determine how or if renewable energy projects will be incorporated. As result, a significant number of local municipalities and counties have expressed concern and have requested that planning authority be restored to local governments. At the time of this article, 76 municipalities have expressed concerns regarding the development of renewable energy projects (Wind Concerns Ontario, 2011). The disempowerment of local councils and residents is perceived as a loss of democratic rights and social justice.

Section 2 of the Green Energy and Economy Act (2009) states, "This Act shall be administered in a manner that promotes community consultation." However, in practice, the community consultation process does not include the right to approve or not approve IWTs in individual communities.

In a reported statement by former Minister of Energy and Infrastructure, George Smitherman: "We passed a law, and the law does not create an opportunity for municipalities to resist these projects just because they may have a concern" (Hendry, 2009).

Impact statements from other parts of the globe report concerns regarding IWT development and social impacts to the local community:

> We are Japanese concerning about wind farm developments. Big wind is destroying nature and local communities in Japan too. People near wind farms are suffering from low-frequency noise from the turbines. (Y. T. O., personal communications, 2010)

M. R. from Australia notes,

> . . . the social division; the slander, lies and intimidation; the anxiety that is caused by the health problems whether they are real or imagined. Again it is how dismissive the neighbours, authorities etc are, of the claims of people who have been affected. Then there is just the total destruction of small communities—pitching one faction against another; appearing to spread largesse when it is a farce; interference with the normal political processes in a small country town. (M. R., personal communications, 2010)

Another individual comments,

> Besides all the health problems, friendships, families and local communities have been destroyed forever. It's so sad. Has the government stopped to think of the real cost in all this so called green energy. (M. O., personal communications, 2010)

A. R. reports,

> . . . the social dislocation that the wind farm has caused. There seems to be dismissal of any opinion that is contrary to the wind company, the government. . . . As dissenters, our rights as citizens of Australia have been eroded—they being the right to free speech and opinion, the right of association and thirdly the right to the benefits of our property's that were meant to be protected under planning laws. This community is forever divided and mentally the wounds are incurable. (A. R., personal communications, 2010)

These sentiments reflect a perceived erosion of local democratic rights and loss of procedural justice.

During the course of several years, over 600 IWTs were commissioned in Ontario, Canada. Coinciding with these IWT developments were increasing reports of adverse health effects. After several years of IWT operations, correspondence from the Ministry of Environment, Ontario (2009) stated, "There is currently no scientifically accepted field methodology to measure wind turbine noise to determine compliance or non compliance with a Certificate of Approval limits."

This lack of measurement and enforceability explained in part, why in spite of a growing number of complaints and requests for help, mitigation and resolution for those experiencing adverse health effects was elusive. Ontario, Canada residents' impact statements reflect frustration and disappointment:

> The wind developers get free access to all levels of the Ministry of Environment—when there are discussions about our noise study, we are excluded from the meeting.
> Who do you go to for help?—the government says it's ok—the industry says it's ok—society says it's ok. I follow all the rules—they call me a NIMBY. What can I do—the developer says it has a license and a right to put the turbines there.
> When people can't sleep, the developer always wins. The Ministry of Environment says they're in compliance, even when they aren't. It's not about justice—it's about procedures. (Personal group interviews by the author, 2010)

In Ontario, the Renewable Energy Approval (REA, 2009) process came into effect with the passing of the Green Energy and Economy Act. The REA is a fast tracking system with the intention to streamline the approval of renewable energy projects.

An individual may appeal a REA if they provide

> (d) a description of how engaging in the renewable energy project in accordance with the renewable energy approval will cause,
> (i) serious harm to human health, or
> (ii) serious and irreversible harm to plant life, animal life or the natural environment. . ." (Rules of Practice and Practice Directions of the Environmental Review Tribunal, (July 9, 2010), section 142.1 (s. d. ss. i, ii).

Originally, the Government of Ontario had proposed an even more onerous legal test in that the serious harm to human health would also have to be "irreversible" (Bill 150, 2009, Section 142.1 (3).

Concern has been raised that the process for filing an REA appeal is daunting for the average Ontarian. Those who wish to appeal an REA, must file one within 15 days. This time limit provides little time to organize an appeal. The appeal process has a number of steps with which an environmental lawyer might be familiar, but most residents would not. The legal requirement to prove that the renewable energy project will cause serious harm requires a comprehensive inventory of evidence, including testimony from expert witnesses.

Typically, an REA appellant would face the well-funded legal resources of the government and the project developer. The associated financial costs are a significant deterrent, which would discourage most individuals from filing an appeal.

In spite of these challenges, an appeal has been launched in Ontario, Canada, regarding the Kent Breeze project in Chatham Kent (The Canadian Press, 2011). At the time of writing this article, testimony by 26 appellant and respondent witnesses has been completed. The appeal hearing started February 1, 2011 and final submissions are scheduled for the end of May 2011.

People expressing legitimate concerns that IWT be sited to protect people from harm have been negatively characterized using preemptive stereotyping such as "those opposed to wind," "anti-wind farm activists," "detractors," "opponents," "beyond NIMBY" (Not In My Back Yard), and "BANANAS" (Build Absolutely Nothing Anywhere Near Anything), (Chatham Kent Public Health Unit, 2008; Colby, 2010; Colby et al, 2009; Kelahan & Purslane, 2009).

Martin (2009) reports on comments by the Premier of Ontario, Canada stating,

> He said the new Green Energy Act his government will enact is intended to prevent such barriers to green energy projects and the 50,000 jobs they bring. "We are going to find a way, through this new legislation, to make it perfectly clear that NIMBYism will no longer prevail," he told reporters at a luncheon gathering of the London chamber of commerce.

An impact statement in response to the Premier of Ontario's allegations of NIMBYism expressed an absence of fairness and stated, ". . . it lowered my sense of value and insulted my personal integrity—and it was coming from the highest office of my provincial government (S. M., personal communications, 2011). This individual's family was billeted by the IWT developer for months and ultimately has left their home of decades to live elsewhere.

The practice of using preemptive stereotyping labels such as NIMBYs demonstrates a lack of understanding of the health and social issues faced by individuals and their families. This lack of understanding results in increased feelings of injustice.

Based on my research, people initially welcomed IWTs into their communities and the adverse impacts were unexpected. Impact testimony reveals

> You need to know the problems with wind turbines and people living with them. I know you probably know me. You've probably seen my letters. When the wind turbines started up in early December, we had terrible noise issues, and it was pretty much instant. There were three nights straight we didn't sleep at all. . . . We had no thoughts that we were going to have problems. When the wind turbines were actually going up at our place in the summer, we were putting a double-car garage up at the same time. We had put in a new fence, a new deck, everything. We weren't

> expecting anything. We're not anti-wind, we're not anti-green. . . . When I hear people say, "There aren't problems," and "It's all in their heads," and "They're just unhappy because they don't have a turbine," I don't even know what to do. My government has not been helping. If you guys are going to go push more through—and then, because I came out and starting speaking, I've got people all over the province phoning me and saying, "Help us. We're not getting anywhere with our MPP. Nobody's listening to us." (Hansard, 2009, p. G-517)

Inconsistent government decisions can undermine Leventhal's (1980) criteria of equal treatment of persons resulting in a perceived discrimination.

For example, the Ontario, Canada, government has been inconsistent in its application of setback distances for IWTs. Currently, the on shore setback distances are 550 meters; however, it was proposed that off shore setbacks would be 5 kilometers (Ministry of Environment, Ontario, 2010). Spears (2010) reports regarding the Minister of Energy (Ontario):

> Minister Brad Duguid said the proposed guideline provides clarity to proponents of wind power projects and to people who may be affected by them. "I think it sets to rest the concerns of some moderate people who were concerned that if they go to the beach, they could be looking up at a huge wind turbine," he said in an interview.

Many Ontario rural residents were disturbed by the government's discrimination between the two groups—those living along a shore line and those living inland.

Measure and Understand the Problem and Assess the Impact of Action

WHO (2008) notes, "society must acknowledge when there is a problem monitor and initiate surveillance, then once the problem is identified, conduct research, and finally, take action" (chap. 16, p. 178).

Inconsistent information, including competing claims and denial of IWT adverse health effects has suppressed the stimulus to investigate the reports of those experiencing negative health and other negative impacts.

The Canadian Wind Energy Association's (CanWEA, 2008) website informs visitors: "Scientists conclude that there is no evidence that wind turbines have an adverse impact on human health."

The tactic of denying of health risks by industry has been employed in the past:

> In 1954, the industry established the Tobacco Industry Research Council. Its task was to reassure the public that the industry could responsibly investigate the smoking and health issue and that it could resolve any problems that were uncovered. The Council's real role, however, was "to stamp out bush fires as they arose." Instead of supporting genuine scientific research into the problems, it spent millions of dollars publicizing research purporting to prove that tobacco did not cause cancer. Its true purpose was to deliberately confuse the public about the risks of smoking. "Doubt is our product," proclaimed an internal tobacco industry document in 1969. "Spread doubt over strong scientific evidence and the public won't know what to believe." (Saloojee & Dagli, 2000)

The American and Canadian Wind Energy Association commissioned and funded panel report acknowledges that IWT noise may cause annoyance, stress, and sleep disturbance, which may have other consequences but then inexplicably states in the conclusion: "Sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans." (Colby et al., 2009, p. 5-2)

A draft final report prepared for the Ontario Ministry of Environment states,

> The audible sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, is nonetheless expected to result in a non-trivial percentage of persons being highly annoyed. As with sounds from many sources, research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons. (Howe Gastmeier Chapnik Limited, 2010, p. 39)

The WHO (1999, p. xiii, 32) recognizes annoyance as a health effect. In terms of annoyance and stress from low-frequency noise in general it has been noted, "The noise, typically classed as 'not a Statutory Nuisance,' causes immense suffering to those who are unfortunate to be sensitive to low frequency noise and who plead for recognition of their circumstances" (Leventhall, 2003, p. 5).

An impact statement from Ontario reveals,

> This hum and vibration is not covered in the guidelines. There are no guidelines for interior noise in our house. When the winds are whipping up, and we can't sleep for days and days at a time, there's nothing. You phone the MOE and I cannot tell you how many times I heard, "We're in compliance. We're in compliance." They're in compliance. They're in compliance. In fact, they weren't in compliance. Finally, we dragged it out and got the acoustics study back. It's just been such a fight to get information. (Hansard, 2009, p. G-517)

In response to proposed Ontario requirements that IWT proponents ". . . be required to monitor and address any perceptible infrasound (vibration) or low frequency noise as a condition of the Renewable Energy Approval" (Renewable Energy Approval Regulation, June 9, 2009, p. 15), the CanWEA (2009b) stated, ". . . CanWEA submits that the proposed requirement for infrasound or low frequency noise monitoring as a condition of the REA be removed" (EBR Posting).

Individuals experiencing symptoms report the lack of recognition of their circumstances. An impact statement from G. M. (personal communications, 2010) in the United States reveals, "I am a victim of large IWTs . . . it is time that legislators and public health officials learn about and are held accountable for the terrible health affects inflicted on nearby residents . . ."

In the meantime, a local public health unit responded to an individual reporting IWT adverse health effects: "Our public health unit does not have the recourse, resources or expertise to monitor the health effects of turbines . . . To stray from this course, by pursuing such avenues, would be highly problematic" (B. A., personal e-mail communication, 2009). Ultimately, this individual's family home was purchased by the IWT developer. A nondisclosure clause prevents the family members from discussing specific details of their experience.

The Ontario Chief Medical Officer of Health's (2010) literature review states, "While some people living near wind turbines report symptoms such as dizziness, headaches, and sleep disturbance, the scientific evidence available to date does not demonstrate a direct causal link between wind turbine noise and adverse health effects" (p. 10). However, the literature review does not adequately address effects of noise regarding the indirect pathway, which includes annoyance, sleep disturbance, cognitive and emotional response, and stress (WHO, 2009, p. 62, figure 4).

The health outcomes associated with the indirect pathway are significant:

> Physiological experiments on humans have shown that noise of a moderate level acts via an indirect pathway and has health outcomes similar to those caused by high noise exposures on the direct pathway. The indirect pathway starts with noise-induced disturbances of activities such as communication or sleep. (WHO, 2009, p.138)

The lack of evidence of IWT adverse health effects is cited as the rationale for not conducting health studies.

The industry trade association–sponsored panel report stated: "Panel members agree that the number and uncontrolled nature of existing case reports of adverse health effects alleged to be associated with wind turbines are insufficient to advocate for funding further studies" (Colby et al., 2009 p. 5-2). The president of CanWEA reportedly stated, "We don't support the implementation of an epidemiological study" (Avery, 2010).

At the same time, peer-reviewed scientific articles have identified the urgent need for research on human response to IWT sound (Pedersen, Bakker, Bouma, & van den Berg, 2009; Salt & Hullar, 2010).

In testimony at the Green Energy and Economy Act Standing Committee, Ontarians living in the environs of IWTs asked elected officials for understanding:

> I want everybody to live in my house. Nobody will live in it. I offer to everybody here: Come and live in my house, free.
>
> A government should take all the money we've given in taxes, use some of it to get the science people out there with no association with the wind industry at all—get out there and study this, and don't put up another wind tower or another wind project until you fix the problems. That's what good government does. Good government looks after its people. (Hansard, 2009, p. G-549)

It is expected that "Government's job is to provide citizens with accurate and appropriate information so that they can protect themselves" (Health Canada, 2004, p. 1-1).

A media report from the United Kingdom discussed the suppression of information regarding IWT health concerns: "Civil servants have suppressed warnings that wind turbines can generate noise damaging people's health for several square miles around." The media report cites a U.K. resident: "We abandoned our home. We rent a house about five miles away—this is our fourth Christmas out of our own home. We couldn't sleep. It is torture—my GP describes it as torture. Three hours of sleep a night is torture" (Leake & Byford, 2009).

The CanWEA states: "…findings clearly show there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health." (CanWEA, Revised: April 2009, p.3), However, Health Canada states "In fact, there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health". (Health Canada, 2009)

It was reported,

> Minister of Health Matthews also took on the question of whether the province will undertake a comprehensive health study on industrial wind turbines now that wind farms are becoming more abundant in Ontario thanks to the province's Green Energy Act.
>
> The short answer to the question of the possibility of a full-scale study is no.
>
> "There is no evidence, whatsoever, that there is an issue related to turbines," says Matthews, noting Ontario's Chief Medical Officer of Health completed

> a report, The Potential Health Impact of Wind Turbines, which shows there is no correlation between wind projects and ill health effects. (Heath, 2010)

In an apparent contradiction, the Premier of Ontario, Canada stated in the legislature:

> . . . we're now funding a research chair devoted to putting in place a longitudinal study so we can ensure that we are in fact not compromising the health of Ontarians. I think we're doing exactly what we need to do at this point in our history. (Hansard, 2010, p. 1032).

The $1.5 million in total funding for the research chair is distributed over a 5-year term (Council of Ontario Universities, 2010). In the meantime, IWT projects continue to be approved (Kent Breeze, 2010) and by the time the health research has been completed; more people are expected to be adversely affected.

Meanwhile, impact statements from existing IWT installations reveal chronic distress:

> I begged the Premier to help me, please help me.
>
> It's mental abuse—I will never be the same . . . I have lost all hope.
>
> We wait and wait for help—our hopes are dashed over and over—the problem is never solved.
>
> I write letters and keep hoping the next one will get us out of this. (Personal group interviews by author, 2010)

Similar comments are expressed in other parts of the globe:

> We still have the noise 4 years later and no one has done anything . . . No one came. No one rang, no one wrote. I am still waiting for someone to take some interest. They don't know the impact on our life. . . . They don't care. (L. C., personal communication, 2010)

Other impact statements describe additional negative social impacts, including the inability to earn a living:

> We have lost our health, our home, and no one cares . . . I had to quit my job, a job I dearly loved. (N. S., personal interview, 2010)
>
> I am a teacher, we are driven from our home of 31 years and I have to teach the social marketing about wind turbines to our youth. (S. M., personal interview, 2010)

G. W. from Australian reports a similar issue about livelihood:

> I've been living in [city y] for 25 years. I live and work from home. The nearest cluster of turbines is approximately 3.25 kilometres from my home. Since the operation of the . . . Windfarm I have suffered headaches, ear aches, ear pressure, head pressure, tinnitus, severe sleep disturbance and mood swings. All of which living in a tranquil bush environment I had never experienced before. These symptoms disappear when I am away from home. The symptoms present themselves again on my return home. These health issues have had a significant detrimental effect on my capacity to work as an artist. (G. W., personal communications, 2010).

In 2009, an increasing number of media reports documented some individuals in Ontario were experiencing adverse health effects from IWTs. In response to the lack of IWT vigilance monitoring in Ontario, volunteers established a self reporting health survey in March 2009. WindVOiCe (Krogh et al., 2011) follows the principles of Health Canada's *Canada Vigilance Programs* for reporting adverse events for prescription and nonprescription products, vaccines and other. Individuals do not have to prove the effect, only perceive it. Under Canada Vigilance, the pharmaceutical industry is obligated by law to submit any reported adverse health effects it receives to Health Canada (Health Canada, n.d.). This obligation to report adverse effects does not apply to wind energy development in Ontario.

The lack of a post–market monitoring methodology to measure wind turbine noise and its compliance with the Ontario IWT noise guidelines is a serious lapse in responsible and fair policy making.

In Ontario, the inability to measure IWT noise for compliance has resulted in a lack of mitigation and resolution for those reporting IWT adverse health effects and other associated societal impacts.

In 2010, after several years of IWT development and operation, the Ministry of Environment, Ontario, released a request for proposal (RFP):

> The Ministry requires a consultant to assist in the development of a measurement procedure to assess noise compliance of existing wind farms with the applicable SOUND level limits. The resulting procedure can be used both by operators of existing wind farms to assess compliance and by Ministry abatement staff in assessing compliance with noise limits. The measurement procedure must address two scenarios.
>
> - Assessment of compliance in a noise complaint situation
> - Assessment of compliance in the context of an acoustic audit. (MERX# 189608, 2010)

At the time of authoring this article, the protocol is still under development. In the meantime, individuals continue to report IWT adverse health effects which are not resolved.

Discussion

The impact statements in this article represent a small sample of a larger body of data acquired through the WindVOiCe health survey, official reports of debates, personal interviews, and other communication.

It is acknowledged that IWTs, if not sited properly, can adversely affect the health of exposed individuals. In addition to physiological and psychological symptoms there are individuals reporting adverse impacts, including reduced well-being, degraded living conditions, and adverse societal and economic impacts. These adverse impacts culminate in expressions of a loss of fairness and social justice.

The above impacts represent a serious degradation of health in accordance with commonly accepted definitions of health as defined by the WHO and the Ottawa Charter for Health Promotion.

Wind turbines are a new source of community noise to which relatively few people have yet been exposed (Pedersen et al., 2009). Public policy to adopt renewable energy as an alternative energy source has inspired governments to introduce measures to encourage rapid development. This has resulted in many IWTs being sited in close proximity to human habitation.

Ontario's Green Energy and Economy Act (2009) is reported to be designed to remove barriers to renewable energy development such as removal of local planning authority. The Act arguably erodes individual human and environmental rights. The Act is written such that a renewable energy development can be approved even if it will cause harm to human health and serious harm to plant life, animal life or the natural environment.

As discussed in the introduction, fairness can be defined as "the recognition and reasonable accommodation of one another's legitimate interests, claims and rights" (Shain, personal communication, 2011). Evidence indicates the rapid implementation of IWTs has circumvented fairness. My research demonstrates that IWTs were initially welcomed into communities. The reported adverse impacts were unexpected. Individuals initially believed there were systems in place that would resolve the problems. Instead, those adversely affected report receiving little if any recognition or reasonable accommodation of their legitimate interests, claims, and rights. A review of IWT development in Ontario indicates that the application of fair process and social justice criteria as proposed by Leventhal (1980) and WHO (2008) are not being achieved.

This subject provides research opportunities for clinicians and social scientists. There are unanswered questions about the risk of short and long term exposure to IWTs. The long-term health impacts to infants, children, and the unborn, family members, and workers such as farmers and technicians who live and work in close proximity to IWTs are unknown.

The long-term psychological, economic, and social impacts on families who have abandoned their homes or been bought out by IWT developers but are silenced by nondisclosure clauses are also unknown.

Conclusions

In Ontario, Canada, there is a suspension of critical appraisal and due process regarding IWTs. The lack of confidence in the political and regulatory systems will persist if governments and industry continue to deny the existence of adverse impacts from human exposure to IWTs.

Societies concerned with health place value on the individual: "A society that is concerned with health and health equity acknowledges the existence of all its citizens and the importance of their well-being" (WHO, 2008, p. 177).

Good governance implies that governments have a responsibility to correct policies that result in harm. Governments have the power to halt development of IWTs in close proximity to humans until authoritative human health research has been completed. Facilities where there are reports of adverse health effects should be decommissioned and health and quality of life restored.

The negative psychological effect of disempowerment interacting with the adverse health effects attributed to IWTs has intensified the negative synergy of justice lost. Impact statements indicate that the violation of procedural justice will not be easily forgotten.

It is expected that this topic will be explored by health care professionals, psychologists, and social scientists for decades to come.

Author's Note

I would like to express my appreciation to the many who have shared their experiences with me. Most of the author's research has been conducted in Ontario, Canada; however, effort has been made to include an international perspective.

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Bio

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Intervenors' Responses to
Staff's First Set of Data Requests
EXHIBIT 6

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WindVOiCe, a Self-Reporting Survey: Adverse Health Effects, Industrial Wind Turbines, and the Need for Vigilance Monitoring

Carmen M.E. Krogh[1], Lorrie Gillis[2], Nicholas Kouwen[3], and Jeff Aramini[4]

Abstract

Industrial wind turbines have been operating in many parts of the globe. Anecdotal reports of perceived adverse health effects relating to industrial wind turbines have been published in the media and on the Internet. Based on these reports, indications were that some residents perceived they were experiencing adverse health effects. The purpose of the WindVOiCe health survey was to provide vigilance monitoring for those wishing to report their perceived adverse health effects. This article discusses the results of a self reporting health survey regarding perceived adverse health effects associated with industrial wind turbines.

Keywords

Self-reporting, adverse health effects, industrial wind turbines, health survey, vigilance monitoring

Introduction

Many Ontarians living close to industrial wind turbines (IWTs) who believe they are suffering adverse health effects are hesitant to report their symptoms. Individuals report that this hesitancy is because of the manner in which their claims have often been discounted or ignored by the wind energy industry and government officials (Hansard, 2009, pp. G-516, G-547). As a result of a limited number who first came forward to report their symptoms, WindVOiCe was established in March 2009.

WindVOiCe is a self-reporting health survey that collects data about adverse health effects being reported by families living near IWTs. The WindVOiCe health survey follows the principles of Health Canada's *Canada Vigilance Programs*, which encourages all consumers in Canada to self-report perceived adverse health effects from prescription and consumer products, vaccines and other. Medical and health care practitioners are encouraged to report perceived adverse health effects to the *Canada Vigilance*. Consumers do not have to prove the effect, only perceive it. The pharmaceutical industry is obligated by law to submit any reported adverse health effects it receives to Health Canada (Health Canada, n.d.).

The objectives of WindVOiCe are to

document any changes in health outcomes among individuals living near IWTs

if documented, provide information to assess the need for large-scale controlled epidemiological studies and to establish evidence-based and safe residence setback distances.

Methods

Study Design and Participant Recruitment

This is a self-reporting survey based on perceived adverse health effects occurring with the onset of an industrial wind turbine facility.

The WindVOiCe survey questionnaire reproduced that of Harry (2007). The questionnaire is designed to collect basic demographic information and information on any new adverse health outcomes and changes to quality of life since the start of the respective IWT project (Appendix A). Health outcome observations included headaches and migraines, heart

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palpitations, excessive tiredness and sleep disturbance, stress and anxiety, depression, tinnitus, and hearing problems.

A Health Survey Contact Flyer was distributed starting in March 2009 to residents in five project areas where adverse health effects had been anecdotally reported (Appendix B): Melancthon Phase 1 and 2 (Shelburne), Canadian Hydro Wind Developers (Shelburne), Kingsbridge 1 Wind Power (Goderich), Kruger Energy Port Alma (Port Alma), Ripley Wind Power (Ripley), Enbridge Ontario Wind Farm (Kincardine), and Erie Shores Wind Farm (Port Burwell).

The Health Survey Contact Flyer was distributed by Canada Post and in some cases by volunteers who hand-delivered it to mailboxes in the areas where IWTs were situated. The opportunity to participate in the WindVOiCe project also involved distributing notices at community information sessions, by word of mouth, and via the Internet (The Society for Wind Vigilance, n.d.).

A confidential toll free telephone number and e-mail address were provided. Those who contacted the WindVOiCe survey team were assured of total confidentiality and anonymity. There were no restrictions placed on the distribution or access to the survey in communities with IWTs. Individuals experiencing adverse health effects and those who were not were encouraged to fill out and submit a health survey. Both hard copy and rarely, electronic copies, were sent on request. Each interested adult in the home was asked to complete a separate survey, with a minimum age of 18 years and fluency in English specified as requirements. The WindVOiCe health survey could not be used by anyone with any cognitive impairment.

Those interested in participating in the study were provided with the survey, a cover page giving general instructions (Appendix C) and a cover note with mailing instructions (Appendix D). Surveys were typically mailed to those wishing to participate and were returned by Canada Post.

Questionnaire Processing

The WindVOiCe Scrutinizer validated each returned survey. The survey contact lead and scrutinizer transferred results into an electronic database (Microsoft Office Excel 2003). Respondents were given the opportunity to include additional comments and these were transcribed exactly as stated. A strict protocol was employed to protect confidentiality and data integrity of the returned surveys.

Data Analysis

All analyses were performed using SAS 9.22 (2008, SAS Institute Inc., Cary, NC).

Descriptive analyses were performed to investigate and describe participant demographics and frequency of health outcome responses. The association between health outcomes and distance to nearest IWT was also investigated. Distance to the nearest IWT was assessed both as a categorical and continuous variable. Significance of associations when distance to nearest IWT was assessed as a categorical variable involved using Proc FREQ (Fisher's exact test). Significance of associations when distance to nearest IWT was assessed as a continuous variable involved using Proc GENMOD (logit link; binomial distribution). Age and gender were included in the Proc GENMOD model if significant at $p < .05$.

For the purpose of interpreting statistical significance, the following parameters were used:

$p < .05$ = significant
p .1 to .05 = moderately significant
$p > .1$ = not significant

Results

Data Preparation for Analysis

- Number of Ontario WindVOiCe survey participants = 109
- Responses of "maybe," "unsure," or "left blank," were all set to "No"
- Those reporting either Altered Health or Altered Quality of Life included = 102
- Four (4) participants were younger than 18 years and were removed.
- Two (2) participants were much further away from IWTs compared with the rest (5 kilometers) and were removed from further analysis given the distance gap.
- Distance to nearest IWT was divided into four groups based on natural break-points among the participants: 350 to 499 meters, 500 to 699 meters, 700 to 899 meters, and 900 to 2400 meters.

Participant Comments

Survey participants were given the opportunity to volunteer comments. A representative selection of comments is provided in Appendix E.

Discussion

A case report is a descriptive study of a single individual (case report) or small group (case series) in which the possibility of an association between an observed effect and a specific environmental exposure is based on clinical evaluations and histories of the individual(s). Because cases in a case series study are often self-identifying and population controls are lacking (as in this study), it is difficult to investigate and measure exposure–outcome relationships, and it is impossible

Figure 1. Age (years) and gender of participants
Age: mean = 52 years, range = 19-83 years. Gender: female = 52%, male = 48%.

to extrapolate results to the general population as selection bias is always a concern. That said, case reports (or case series) often provide the first indicators in identifying a new disease or adverse health effect from an exposure.

Study participants ranged in age from 19 to 83 years; there was approximately an equal number of males and females enrolled in the study (Figure 1); and the frequency of participants increased with closer distances to IWTs (Figure 2).

In total, 72% of participants reported increased symptoms of anxiety, stress, or depression since the start of their local wind project (Table 1), and not unexpectedly, mental distress was *not* associated with distance to nearest IWT. Distress likely played a major role in individuals self-identifying themselves for the study, and it is reasonable to assume that individuals experiencing distress because of IWTs for *whatever* reason (real or perceived adverse health effect, attitude, etc.) were more likely to participate in the study. Among study participants, the most common adverse health outcomes reported included sleep disturbance, excessive tiredness, and headaches.

Although it is not possible to compare participants to a control group in this study, it is possible to investigate relationships between exposure levels (as measured by distance to IWT) and outcomes *among* participants. Results suggest dose–response relationships between a number of adverse health outcomes and distance to IWTs, particularly sleep disturbance, excessive tiredness, and headaches (Figures 3-6). Modeling efforts suggested stronger relationships between adverse health events and log-distance to IWTs compared with linear distance. This mirrors the way in which sounds decays as it travels from source to receptor.

Discovering relationships between adverse health outcomes and log-distance (Figures 7-9) to IWTs among self-reported cases is a significant finding and supports the underlying hypothesis that living too close to IWTs can cause adverse health effects. If adverse effects were purely psychosomatic (i.e., the result of emotional distress and fear), one would expect the proportion of individuals self-reporting to increase closer to IWTs in this alternative hypothesis; but among those who did self-report, one would *not* expect dose–response relationships. Lack of a true cause–effect relationship should have resulted in relationships with distance to IWTs as seen with stress, anxiety, and depression (i.e., the primary drivers of self-reporting in this alternative hypothesis).

It is noted that the comments excerpted from the survey range from descriptions of altered quality of life and enjoyment of property, health issues related to noise, flicker and sleep disturbance, altered social and family interactions, concerns about property values and altered financial status, changes in pet and wildlife behavior, and concerns about the future. Some describe the impact on the family unit when a parent or spouse has been billeted at the developers' expense because of adverse health effects. These comments were voluntarily submitted by participants.

Conclusion

Self-reporting is an important research tool and frequently used by the research community. Examples of the use of self-reporting include peer-reviewed articles by Engstrom, Paterson, Doherty, Trabulsi, and Speer (2003), Meyer, McParlan, Sines, and Waller (2009), Zota, Aschengrau, Rudel, and Brody (2010), and Lim et al. (2010). In addition, self-reporting is encouraged with respect to breast cancer vigilance where women are encouraged to conduct routine breast examinations. This self-monitoring is used as an adjunct to other monitoring procedures such as mammograms and checkups by physicians.

It is important not to overinterpret results of a self-reporting case-series study. Outcome measures are crude, and the lack of a control group and potential selection bias prevents investigating traditional population-based epidemiological measures of association (e.g., odds rations, relative risk, etc.). Careful analysis of case-series data, however, can provide important initial indicators regarding underlying causal relationships, providing support for more thorough and larger scale epidemiology studies. Results of this study suggest an underlying relationship between IWTs and adverse health effects and support the need for additional studies.

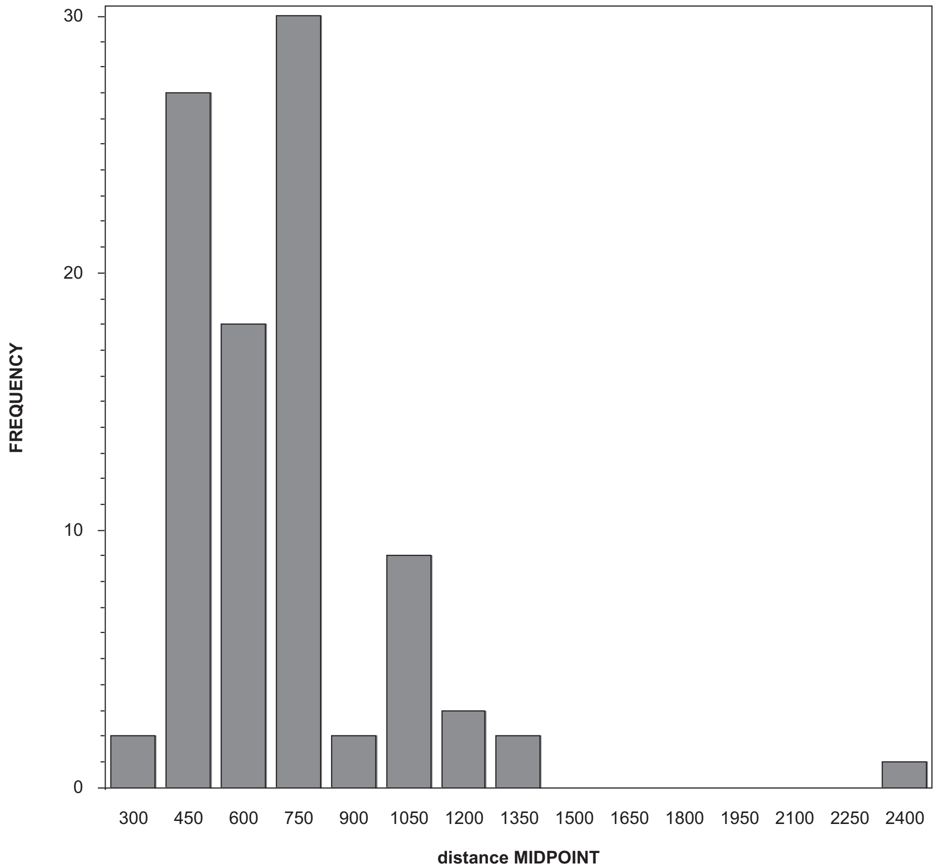

Figure 2. Distance of participants to nearest industrial wind turbine (meters)
Distance: mean = 707 meters, range = 350-2400 meters.

Table 1. Health Outcomes Results

Parameter	All Participants	Distance Range From Residence to Nearest IWT in Meters (Mean) 350-490 (428)	500-673 (587)	350-673 (506)	700-808 (769)	900-2400 (1154)	700-2400 (908)	p[a]
Number of responses	97	24	23	47	30	17	47	
Altered quality of life (%)	97	96	96	96	100	94	98	1.0000
Altered health (%)	90	93	96	94	87	82	85	.1908
Disturbed sleep (%)	69	78	78	78	60	59	60	**.0778**
Excessive tiredness (%)	76	89	83	86	63	71	66	**.0307**
Headaches (%)	62	74	65	70	60	41	53	**.0990**
Migraines (%)	13	22	13	18	13	0	9	.2358
Hearing problems (%)	35	22	57	38	27	41	32	.6706
Tinnitus (%)	56	59	61	60	33	41	51	.4179
Heart palpitations (%)	34	26	39	32	33	37	36	.6750
Stress (%)	69	74	57	66	70	76	72	.5189
Anxiety (%)	52	52	57	54	40	65	49	.6864
Depression (%)	41	44	48	46	33	41	36	.4099
Distress[b] (%)	72	74	61	68	73	82	77	.3735
Approached doctor (%)	38	37	39	38	40	35	38	1.0000

Note: Significant or moderately significant p values are in the boldfaced.
[a]Fisher's exact test.
[b]Distress = "Yes" if at least one of stress, anxiety, or depression reported as "Yes."

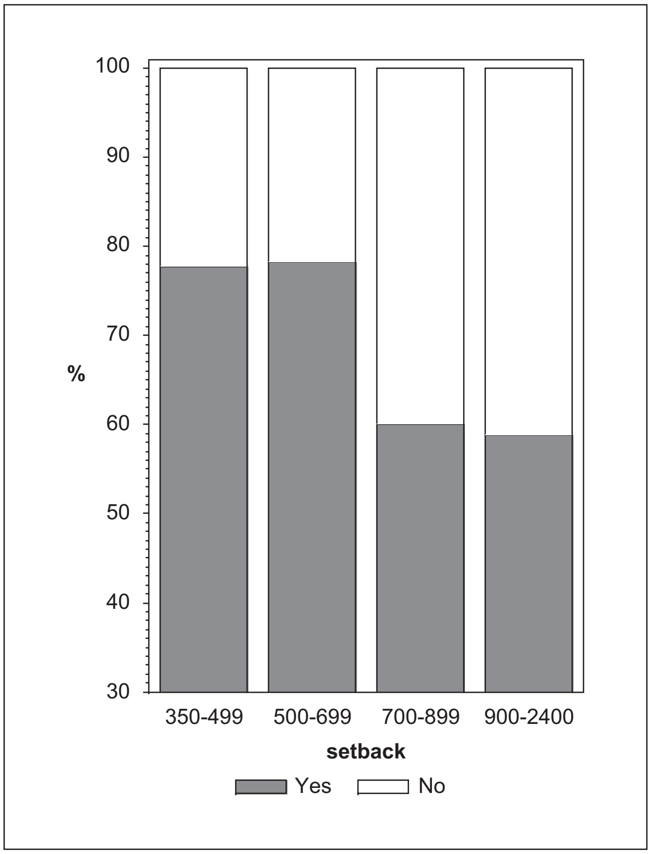

Figure 3. Sleep disturbance by distance (meters)

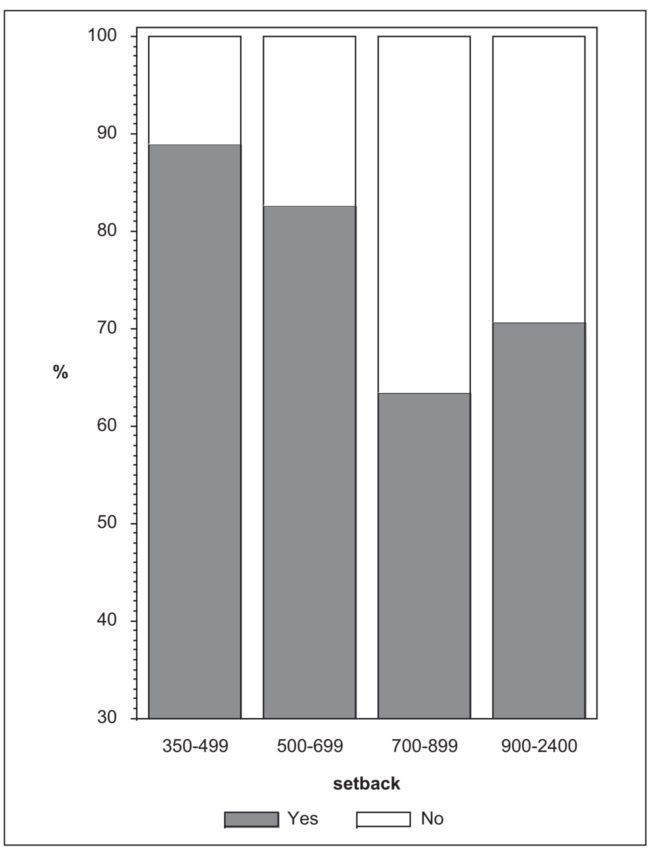

Figure 4. Excessive tiredness by distance (meters)

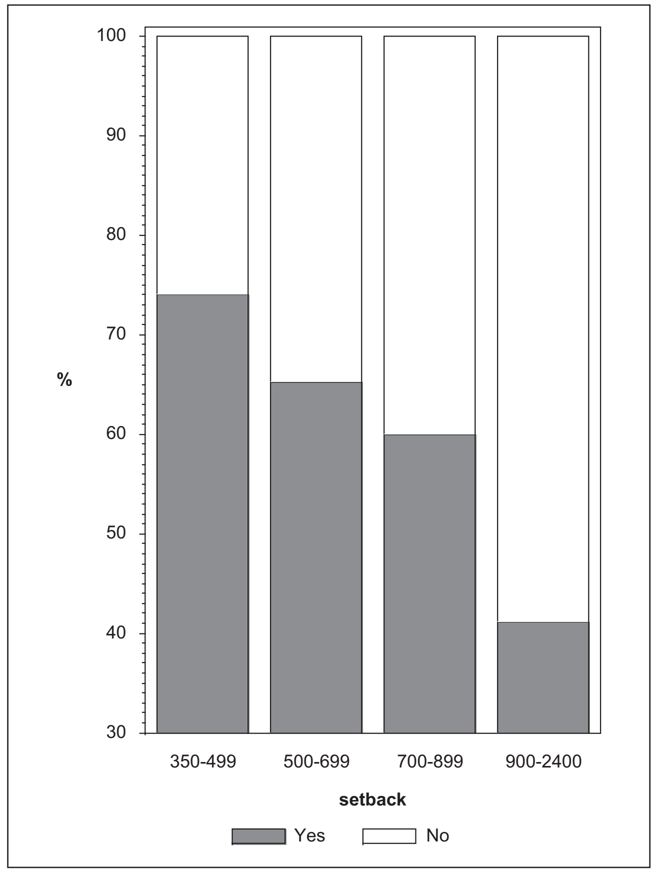

Figure 5. Headaches by distance (meters)

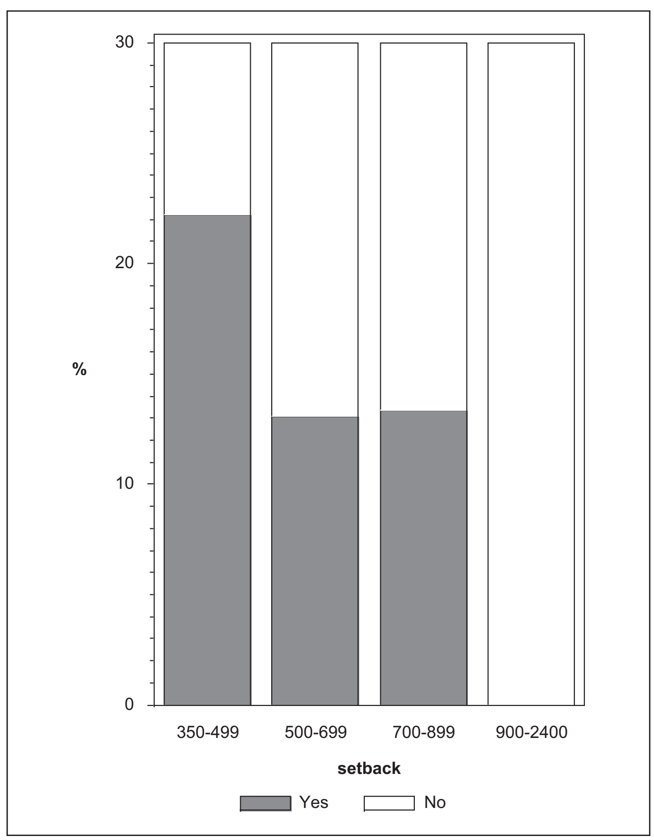

Figure 6. Migraines by distance (meters)

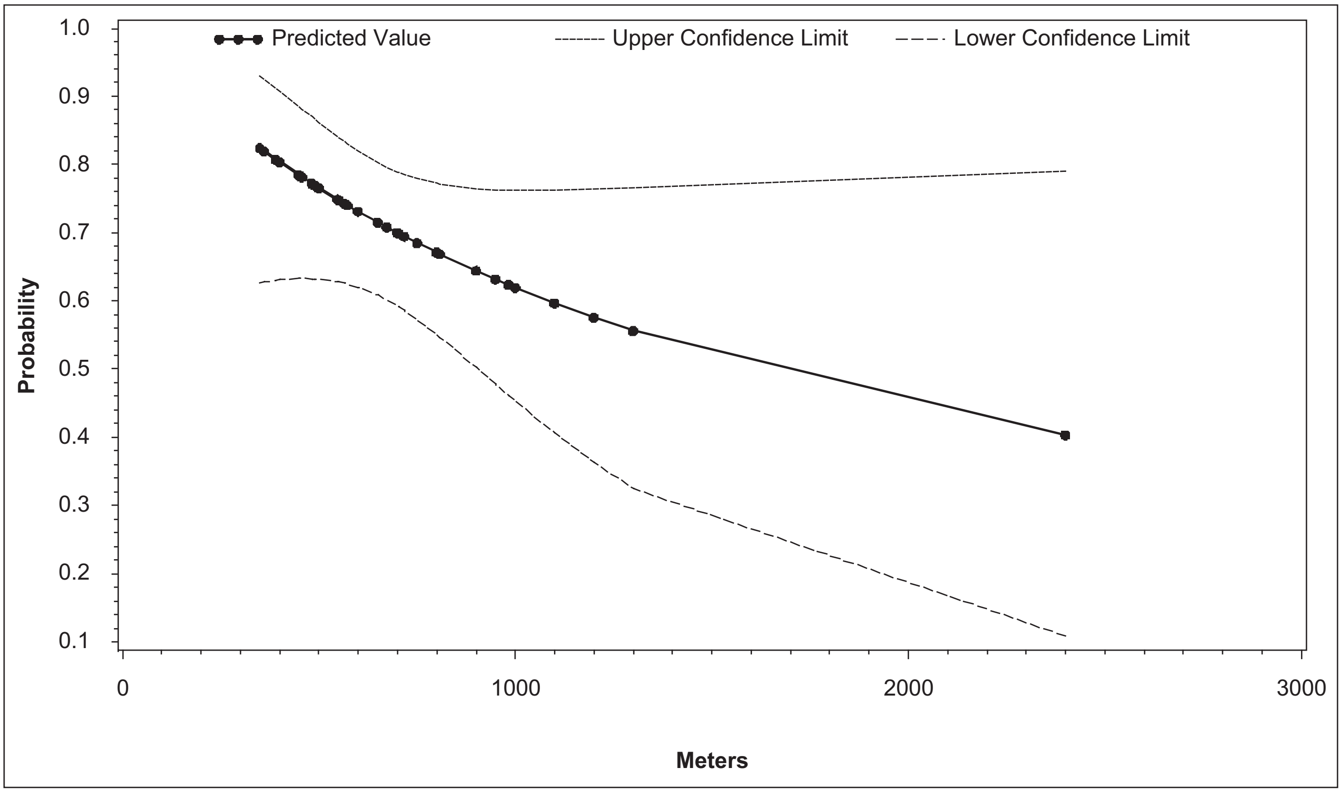

Figure 7. Predicted probability of sleep disturbance by distance to industrial wind turbine (95% upper and lower confidence limits)
Proc Genmod (logit link; binimoial distribution). Sleep = ln(distance) + sex + intercept. *p*(ln distance) = .1015.

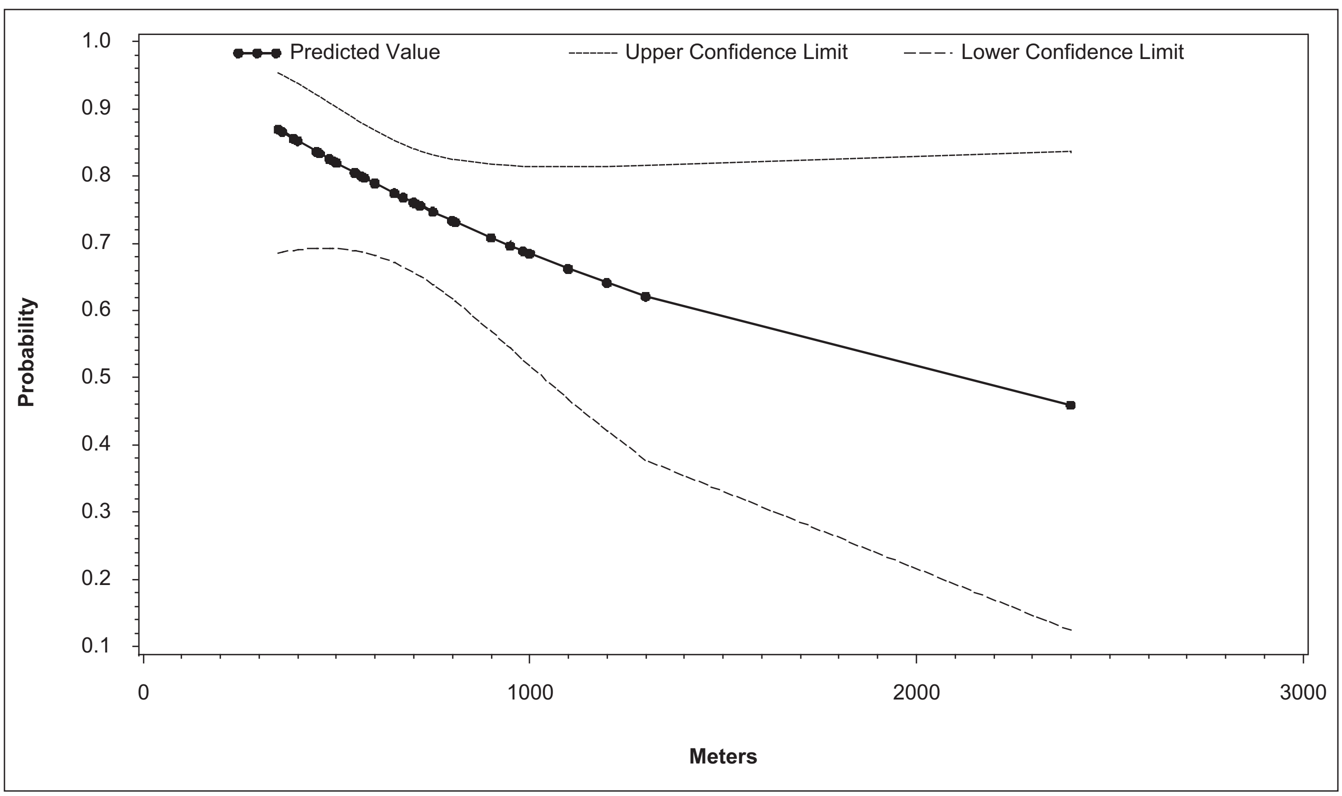

Figure 8. Predicted probability of excessive tiredness by distance to industrial wind turbine (95% upper and lower confidence limits)
Proc Genmod (logit link; binimoial distribution). Excessive tiredness = ln(distance) + sex + intercept. *p*(ln distance) = .1005.

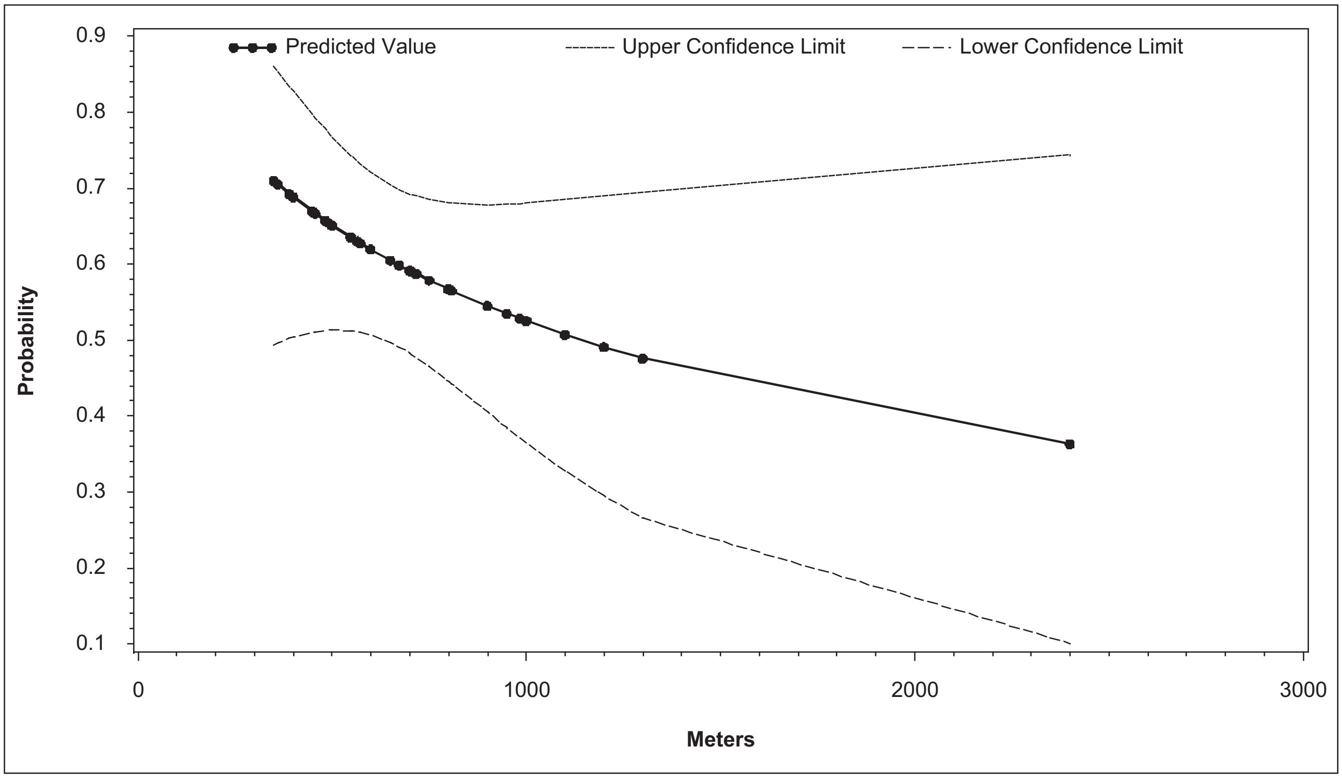

Figure 9. Predicted probability of headaches by distance to industrial wind turbine (95% upper and lower confidence limits)
Proc Genmod (logit link; binimoial distribution). Headaches = ln(distance) + sex + intercept. p(ln distance) = .1837.

Appendix A

WindVOiCe Survey Questionnaire

Adult survey questionnaire:
WindVoiCe (Wind Vigilance for Ontario Communities)

1) Name (preferred but optional)

2) Date of birth

Day _______ Month __________ Year _____________

3) Occupation _____________________
4) Address and/or postal code

____
____
____
____

5) Which wind farm is near your property?

____
____

6) How far away from your property is the nearest turbine?

____

7) How long have you been living at this property?

____

8) Do you feel that your health has in any way been affected since the erection of these turbines?

____

If yes, please answer the following
Do you feel that since living near a wind turbine/turbines you have experienced excess of the following symptoms (i.e., more than you did prior to living near these structures)?

Headaches	yes _____ no _____
Palpitations	yes _____ no _____
Excessive tiredness	yes _____ no _____
Stress	yes _____ no _____
Anxiety	yes _____ no _____
Tinnitus (ringing in ears)	yes _____ no _____
Hearing problems	yes _____ no _____

(continued)

Appendix A (continued)

Sleep disturbance yes_____ no _____
Migraines yes_____ no _____
Depression yes _____ no _____
Other—please specify

If you have answered yes to any of the above questions, have you approached your doctor regarding these symptoms?

yes _____ no _____
If yes, please state any tests and/or treatment initiated

9) Do you feel that your quality of life has in any way altered since living near wind turbines?

yes_____ no _____

10) If yes, could you please explain in what way you feel your life has been altered?

11) If you have any pets or livestock and have seen any changes in their behaviour since turbines have been erected, please describe

Appendix B

Health Survey Contact Flyer

WIND ENERGY CONCERNS?

Industrial wind turbine installations are becoming one of the most prolific forms of energy being put into use today.

Some residents living in the vicinity of a wind farm are suffering from adverse health effects and disturbed living conditions.

People from across Ontario who welcomed wind turbines into their community are now coming forward with questions and concerns and may not know where to turn.

If you, or anyone you know is having difficulty, please call *toll free 1-888-700-5655* or email *windaffects@gmail.com* Others are facing similar concerns.

Your call will be kept totally confidential.

Appendix C

Health Survey Cover Page

WindVOiCe (Wind Vigilance for Ontario Communities)

Questionnaire on Health/Disturbed Living Conditions

Some residents living in the vicinity of wind turbines are suffering from adverse health effects and disturbed living conditions.

Currently, there are no authoritative guidelines about how far away turbines should be placed from residences. We are collecting information so that we can advise those in authority about the impact wind turbines have had on some of our population.

Your name will be kept totally confidential.

How to use the questionnaire:

1. If more than 1 adult in the home is affected please have each adult fill out a separate questionnaire.
2. This questionnaire may be filled out by a person 18 years of age or older who is fluent in English. This questionnaire will NOT be used by anyone with any cognitive impairment.
3. Question 5)—please answer with project name and/or wind company name. Question 6)—please give estimate if exact number is unknown. Question 10)—open to any other life alterations you've noticed for yourself. Please, worried parents, use this space to describe any symptoms your children may show.

Lorrie Gillis
Health Survey
R.R. #4
Flesherton, Ontario N0C 1E0

Thank you for taking the time to fill out this questionnaire.

Appendix D

Health Survey Cover Note

Cover Note accompanying the survey with mailing instructions

Thank you for being part of this survey. Your participation gives voice to adverse health and living conditions to people living in close proximity to industrial wind turbines. Confidentiality of your personal information is assured. Results will go forward with no disclosure of any personal or identifying information. All surveys will be kept in locked storage at all times with extremely limited access for tabulation of data. Please return your completed survey to:

Lorrie Gillis
Health Survey
R.R. #4
Flesherton, Ontario N0C 1E0

Appendix E

Sample WindVOiCe Participant Comments

3

9) [other] High blood pressure 217/124

Had a foot that don't heal until I moved out of the house

Yes [contact doctor] Blood pressure, urine test, Doppler test, heart machine, on blood pressure pills now (Mavik 1 mg) Trandolapril [sp?]

10) [quality of life altered]

1. Had to move out of my home, just come home now to feed the cattle.
2. Our home can't be sold due to the problem per real estate agent.
3. Family events can't take place at home
4. Financial problems due to keeping two homes
5. Always sick, depressed and bad tempered when at home but when away for a short time feel much better. (Much better in the second house which I had to buy)
6. Had family problems until we moved out.
7. Feel no cares or believes us.

Bottom line:

They took life away as we knew it before the wind farm, same house value 0 sick all the time, financial stress now, world turned upside down.

11) 2 house dogs always sleeping, ear problems itching all the time. Moved the dogs out of house, now they are fine.

13

10) [quality of life altered] Everything in my life has changes since the town_x Wind Turbine Project company_x has been in operation. I feel my health has been compromised. I have felt generally unwell physically and mentally since March 24/08. Also sensitivity to white noise and sounds has increased. My ears are either humming or feeling pressure on them/heart palpitations continue usually while sleeping. My anxiety and stress levels continue to be high. We have discouraged our two daughters and son-in-law from visiting. They have also experienced health issues when visiting. The damage that has been done to my body—scares me what will happen in the future. At 60—I wanted to enjoy my retirement with reasonable good health and now everything has blown up in our faces. We spent 5 weeks in Florida Jan 26—March/09 improvement in health. Loss of enjoyment of working outside with flower beds and yard. Our property value has been greatly decreased. We are still having problems with electrical pollution. Constant reminder in every direction of our property—turbines. A very uncertain future!!

#18

8) [health affected] Yes—whenever I am there!

9) [other] [other] Pressure in my ears or ear aches tightness feeling in my head

[doctor visit] Not at this time, these symptoms only occur around the Wind Project and not at my own residence.

10) [quality of life altered] As a teacher who spends most of my summer relaxing at home& was disrupted in July/Aug 2008 when I would leave each night with my mother to drive 10 min to a hotel town z in because of the above symptoms. This is something she did for months, it was disruptful for the few weeks I did it, not a peaceful relaxing environment. In December 2008 when I arrived home to my parents on the first night for Christmas the pressure in my head and ears hurt so bad that I had difficulty sleeping and considered spending the rest of the week at a relative's home away from the wind turbines. These are regular occurrences when I visit, and now sometimes think twice before going as I don't know how bad it will be this time, which makes going home no longer relaxing and peaceful like it once was. I also worry on a daily basis for the health and well being of my parents who live through this daily and the negative health impacts and stress worries me greatly. It also causes me stress that the value of my family farm has dramatically been reduced due to these wind turbines.

11) Thank you for organizing this health survey. My family greatly appreciates it.

#34

[palpitations] pressure in chest, dull and stabbing pain in chest

9) [other] joint pain, numb face, dizziness, feeling cold a lot.

Yes, doctor is aware and looking for a referral to an environmental specialist—so far no luck—not sure what next step will be.

10) [quality of life altered] Along with the above symptoms—experiencing a general lack of wellness.

#40

Struck/heart palpitations

9) [other] Stress tests/blood tests too numerous to count.

10) [quality of life altered] I now live on drugs that don't seem to help.

11) Livestock were all sold off due to problems that could not be explained. (Nervousness)

(continued)

Appendix E (continued)

#41

10) [quality of life altered] Forced to sell our property, take less than what it was really worth!! This was due to health problems caused by the wind turbines.

11) Our dogs were nervous, as well as our four (4) ponies. We ended up taking our ponies to the auction barns and had them sold. Two of our dogs had to be put down!!

#46

9) [other] No. Problems with the above go away when I leave the (wind project) home.

10) [quality of life altered] I feel wound up when at home. I just cannot settle. Because of this I do not want to stay in our home or for that matter come home. The biggest change has been the effect on my Mom, sister and Dad's health, especially Mom. To see her suffering from health problems, getting sicker and sicker just pisses me off. It really bothers me a lot.

#50

9) [other] [tinnitus] pop when turbines come on and off.

[sleep disturbance] Do not sleep a full night. Wake up quite often.

[other] nasal cavity felt like I had allergies, but no mucus, irritable.

10) [quality of life altered] Personal—have found the changes in sleep patterns reduced energy levels, levels of patience and very frustrating and draining. Dec. on there were serious, angry arguments we normally do not have. I am *very worried* about my partner's, [wife], reduced sleep/rest, humming/ringing in her ears and continued deterioration of health. When [wife] had to live away from home it was hard. She is my partner and my love. We would always chat on family plans from food to finances. Our lives were upside down at all family levels when she was billeted by the windmill company wind_co_x from May 2008 to July 17th and AGAIN now. She is living at her Mom's in town_y a 30-minute drive away (on Dr. orders). On a very personal level I am like a widower and sad and lonely.

Generally—Our financial outlook for our property has changed. At present we cannot sell knowing the possible harm that someone may experience. This is a stressor we did not have prior to the turbines. I can't sleep with the bedroom window open in the summer for a cool breeze due to the roaring jet sound. (This was pleasant and cooling too.) I can't have a quiet sit on the deck without the jet or swoosh sound. And our phone has static on it which is not there when turbine were not here. CKNX am channel is staticy or weaker in the project area.

#58

10) The flicker from the turbines can be very annoying in the mornings. When I'm training horses for 3 to 4 hours the noise gets to you and you have to stop for awhile and go to the house. In the summer when windows are open you can hear them in the house. There is also some problems with some of the neighbours around me because of stray electricity. I have not had mine checked.

When the turbines are noisy, the horses always go to the far side of the barn.

#61

9) [other] Yes, doctor did blood tests, oral scope, prescribed sleeping pills, referred me to therapist and a nutritionist, sent me to a sleep clinic, I was vomiting blood.

10) [quality of life altered] We lived in this house for twenty years with the plan that we would pay it off, borrow money to purchase our retirement home and then sell the house to pay for the retirement home. We put the house up for sale the year before the turbines were built and real estate agents told us, people were worried about where the turbines would be placed and the house did not sell. Now the turbines are up and I can count 30 of them from my property. My wife and I can hear them when we are outside and we experience flicker when we are inside. We can see them through every window in the house in the daytime and we see the sea of red flashing lights every night. We live in a school house we took from being vacant for twenty years to a beautiful open concept home in a quiet country setting. Our friends and family have loved our home for years but now just shake their heads when they [see] what has happened here. Don't know what's going to happen to me in five years when I'm ready to retire if I can't sell my house.

#69

10) [quality of life altered] We bought this property to be away from the noise of the city and road traffic now all I hear is the windmills. I love to be outside, walking, hunting in our bush. Now all I hear is the windmills. Peace and quiet no longer exists. The rear of our house is all windows, at night all you see is the warning lights. It is driving me crazy. We had no say in the mills because we weren't getting one. The persons that got them get paid and don't live near them. I'm sure our property value has went down because of them. This summer will be the first time we can lay by our pool and I'm sure they will drive me.

#78

9) [other] [Doctor] Discussed symptoms with doctor twice. At this point we will further monitor my symptoms and discuss possible actions (tests, etc.)

10) [quality of life altered]This previously peaceful/quiet area was to be our retirement home. We are now considering changing our plans. Any further improvement to this property is on hold.

Depending on wind direction there is a loud pulsating, intrusive swooshing noise. I seem to sense a vibration in the air and at times I seem to sense the changing air pressure (like descending in an airplane.)

I spend 80% of my time in [turbine town x] and 20% in [town y]. When in [town y] I sleep better, less headaches and more relaxed.

#83

9) [other] nausea, muscle pain, irritability

10) [quality of life altered] To avoid morning flicker must have blinds or avoid rooms until it passes. When warm weather arrives noise from turbines will limit opening of windows especially at night for sleeping.

Will not enjoy evenings out of doors on decks due to all the Red Flashing lights and noise.

#88

9) [other] Have no family doctor. Went to emerg currently awaiting a CT scan.

10) [quality of life altered] Constant noise, constant headaches. Sleep disturbance since the wind towers have started.

We have recently put a 500′ addition on our home with large windows all around. Not only we get flickering from the towers we cannot open any windows due to the constant noise of the blades.

My occupation is a bookkeeper. These constant headaches are affecting my concentration, especially working with numbers. I work from my home. I simply cannot afford to be in ill health.

I can no longer sit on my back porch enjoying the beautiful sunsets. This was so relaxing to me. Now all I see is flickering blades and blinding red lights. The sunsets have disappeared into money hungry pockets of our government.

This area was once known as having the most beautiful sunsets in the world, now gone!

I now am a prisoner in my own home of 23 years.

This is not the future I wanted! That is why I bought this property 23 years ago. Now I am going to sell and start all over again. Extremely depressing!

11) My horses are nervous of the noise and do not focus on what they are doing. Instead they watch the windmills making this a danger when riding or training them. My dogs and cats want to stay in the house more now. This is very unusual for them.

#107

8) Biggest factor is the noise.

Unable to sleep with windows open at night and I'm a poor sleeper under good conditions. Find when I'm outside gardening or reading, the constant noise from the blades turning very irritating and I find I have a pressure in my ears that wasn't there prior to the last few months.

#110

8) [health affected] yes, (mostly mental health)

9) [other symptoms] cannot deal with noise

10) [quality of life altered]—cannot enjoy the outdoors and sounds of nature because of noise

hesitate to invite friends over

feel upset that we built our amazing energy efficient ICF home in an area full of horrible noise pollution.

feel violated

upset that my lonely elderly mother came to live with us to have a happier life but now has vertigo (we have not mentioned to her the possible correlation to windmills.)

feel like we should have known better!

we trusted township and [wind company]

#130

6) [distance from turbines] approx 400m but there are 10 of them within 1 mile of our home.

8) [health affected] YES—WITHOUT A DOUBT!!!

9) [symptoms] [palpitations] not sure, [excessive tiredness] I have trouble sleeping, [tinnitus] sometimes, I've just noticed it. [other] I don't know if it's palpitations or anxiety, but sometimes my heart races like it's going to jump out of my chest.

10) [life altered]

I now have great trouble getting to sleep in fact I now use sleeping pills, I never used to, EVER!!!

I can no longer enjoy my home outdoors, There is a constant "buzzing" that I cannot escape. The further that I walk onto my vacant land, the closer I get to the neighbors tower—these towers make me feel constantly stressed and I always am anxious or have a feeling of anxiety.

I worry about my plummeting real estate value, and if a bank will even renew my mortgage when its time.

I'm in a position that if I complain, I fear that my property value will fall even further. [identifying comment left out]

myself and other members of my family are now getting unexplained headaches, even my [age] year old daughter who has never had a headache prior to these towers coming online. I have a feeling of helplessness because I want to get away from the towers but we must remain due to the fact that we can't afford to abandon our home and move.

11) Our dog is restless constantly pacing

#133

9) [other symptoms] Lack of focus—Lack of Concentration—Memory loss—High Blood Pressure—Nausea—Feeling of Fullness in the Head—Fullness Feeling in the ears

[approached doctor] Weekly pain clinic and migraine treatments. Pain medication for migraine. Nausea medication. Anti-hypertensive medication. Anti-depressant medication. Several types of pain medication. Acupuncture and Chinese Medication. Acupuncture bi-weekly.

(continued)

Appendix E (continued)

10) [life altered]

1. Lost my career, which I loved dearly. It was a part of my life since age 18. *A huge loss*.
2. Lack of sleep has caused an enormous amount of stress; has impacted my everyday life from everyday appointments to social events + friendships; routines of living such as shopping, house cleaning, gardening; entertaining and family gatherings.
3. I was an avid reader but I cannot sit and concentrate to read a book.
4. I'm exhausted most of the time.
5. I feel tense all the time.
6. My ill health has become a major focus of my life and I fear a major fear of having a stroke!
7. I don't have people in my home anymore.
8. All our needed home renovations are on hold.

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Bios

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Occupational Health and Industrial Wind Turbines: A Case Study

Robert W. Rand[1], Stephen E. Ambrose[2], and Carmen M. E. Krogh[3]

Abstract

Industrial wind turbines (IWTs) are being installed at a fast pace globally. Researchers, medical practitioners, and media have reported adverse health effects resulting from living in the environs of IWTs. While there have been some anecdotal reports from technicians and other workers who work in the environs of IWTs, little is known about the occupational health sector. The purpose of this case study is to raise awareness about the potential for adverse health effects occurring among workers. The authors propose that there is a need for research regarding occupational worker exposure relating to IWTs.

Keywords

industrial wind turbines, occupational health, adverse health effects, case study

Industrial wind turbines (IWTs) are becoming more prolific worldwide. Ongoing technical support from engineers, technicians, and other personnel are required to maintain and operate the wind energy facility. As well, farm and other operators such as truck drivers are frequently exposed to the emissions associated with the operations of the wind turbines.

There is a paucity of information relating to the risks to occupational exposure. This article will report on an incident involving worker exposure. It is expected this case study will encourage research on this topic to ensure protection and mitigation of worker exposure.

Setting the Stage

The authors were commissioned to conduct a study at a wind turbine facility where residents were complaining about noise issues and adverse health effects. The complaints were correlated with the start of operations of two IWTs. The study was privately funded under a grant and was independent of any developer or group opposing IWTs.

The purpose of the study was to evaluate the presence or absence of sound in the low-frequency and infrasonic range. The primary area of interest was from 1 to 200 hertz.

Two IWTs were involved—one owned by the township and the other privately owned. Operation of the facilities started in 2010. Prior to the operation of the IWTs, there were no noise complaints such as those now being reported postoperation. The requests for mitigation ranged from complaints, to appeals to stop the noise, to requests for stays of operation with legal representation.

As a result of the complaints, the township capped the operations of its turbine so that at 10 meters per second wind speed at the hub, the turbine was shut off. This is reported to have provided some relief. However, the privately owned turbine was not capped and continued to operate.

The study took place over a 2-day period inside a home where people were experiencing serious adverse health effects. The home owners reported symptoms of nausea, dizziness, irritability, and cloudy thinking; had incurred falls and injury from loss of balance; and were severely affected to the point where abandoning the home was being considered. It is a custom-built, highly insulated, solidly constructed retirement home of 10 years. The home is 1,700 feet (520 meters) from the privately owned turbine and 4,200 feet (1,280 meters) from the township-owned turbine. The terrain is predominately gently rolling rural countryside with modest changes of elevation including glacial moraine, stream valleys, and sand quarries.

Technical Details and Conditions

The study took place over a 2-day period.

Weather Conditions During Study

The weather generally showed an early summer pattern with wind speeds at the hub of 20 to 25 m/s by midmorning. Ground wind speed was light during the day. At night, hub wind speed was light, with ground wind speed about zero

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and no background noise except that of distant traffic, which died off in the early hours of the day. Average wind shear at hub height was documented previously by two independent researchers at 0.47.

Day 1: Changeable with wind speeds 25 to 30 meters per second at the hub, gusting to more than 35 meters/second. Wind direction west–southwest. Barometer "low" and variable. Sunny and partly cloudy. Temperature 45 to 50 degrees Fahrenheit

Day 2: Sunny with wind speeds 15 to 20 meters per second at the hub, gusting to 25 to 30 meters/second. Wind direction west–southwest. Barometer "low" and rising during the day. Temperature 45 to 50 degrees Fahrenheit

Day 3: Winds stopped and the study concluded

Turbine Make and Model

Vestas V82, 1.65 megawatts, hub height 80 meters, diameter 82 meters. Both turbines were manufactured and shipped at the same time.

Distance From the Wind Turbine

Private home, 1,700 feet (520 meters).

Instrumentation

The table below lists the instruments used to perform the study.

Instrumentation list
Outdoor/indoor dual-channel system
Microphone: GRAS, Model 40AN, sn 27538
Preamplifier: Larson Davis, Model 2221, sn 0107
Microphone: Bruel & Kjaer, Model 4165, sn 844497
Preamplifier: Larson Davis, Model 902, sn 0235
Sound meter: Larson Davis, Model 824, sn 0914
Audio interface: Sound Devices USB Pre 2, sn HB0411005004
Acoustic calibrator: Bruel & Kjaer, Model 4230, sn 1103065
Digital audio recorder: M-Audio, Model Microtrack II, sn 138AOC8107245
Computer: Acer 5745 i3cpu, Win7; Spectraplus 5.0, sn 5879.
Roving and stepped distance measurement system
Microphone: Svantek, Model SV22, sn 4012682
Preamplifier: Svantek, Model SV12L, sn 5552
Sound meter: Svantek, Model 949 SLM, sn 6028
Acoustic calibrator: Larson Davis, Model CAL200, sn 2425
Digital audio recorder: Tascam, Model DR100, sn 0030486
Computer: Sony VAIO, Win7, Spectraplus 5.0

Method

Testing was performed primarily inside the home. At times sound measurements were taken simultaneously inside and outside the home. Particular attention was given to measurements below 20 hertz and included determining the noise reduction that occurred between the inside and outside values. Standards ANSI S12.9, ANSI S12.18, and ASTM E966-02 were used. In later analysis, data were digitally compensated for flat response to 1 hertz.

Study Results

Day 1

The authors were unable to prepare their instrumentation or acquire calibrated data from arrival to midnight due to encountering unexpected and severe adverse health effects similar to those described by the home owners. At midnight they left the house and conducted a series of stepped measurements at 275, 830, and 1340 feet (84, 253, and 408 meters) from the turbine. They concluded outdoor measurements due to rain and returned to the house at 1:50 a.m. Long-term recording was conducted indoors from 2 a.m. to 8 a.m. during sleeping hours.

Day 2

The authors left the house to have breakfast and experienced relief from symptoms once they were more than a mile away from the IWTs. They returned later and found that the symptoms returned almost as strongly as the previous day. They conducted a series of tests with inside–outside microphones during the afternoon with winds at the strongest of the day. The wind turbine noise controlled the outdoor sound levels at 42 to 44 dBA.

Day 3

The winds were calm in the morning and the nearest turbine was off. The authors found that the health symptoms were considerably lessened from the previous 36 hours. Recordings were made of the ambient sounds of the morning for comparison to turbine sound during later analysis. Sounds included vehicle operations in a quarry some distance away, distant and occasional local traffic, and birds, with sound levels 32 to 28 dBA.

Findings

Overall, there was a strong correlation between the wind speed, resulting wind turbine operation level, and severe adverse health effects (Table 1). The strongest effects were experienced indoors with hub height winds at 25 meters per second with gusts to 35 meters per second. The strongest correlation between physical symptoms and wind turbine acoustic emissions was judged to be the change in the modulated infrasonic sound level measured in dBG over a quiet background. Low background sound levels and infrasonic levels modulating or pulsing above 60 dBG were found to be

Table 1. Nearest Turbine Data and Adverse Health Effects at House Under Study

Hub wind speed (meters/second)	Industrial wind turbine output (kilowatt)	Study location	dBA	dBG	Symptoms experienced
25, gusts to 35	1,600-1,700	Indoors	NA	NA	Nausea, dizziness, irritability, headache, loss of appetite, inability to concentrate, need to leave anxiety
		Outdoors	NA	NA	Felt miserable, performed tasks at a reduced pace
18-20, gusts to 30	1,350-1,500	Indoors	18-20	51-64	Dizzy, no appetite, headache, felt miserable, performed tasks at a reduced pace. Desire to leave
		Outdoors	42-44	54-65	Dizzy, headache, no appetite. Slow. Preferred being outdoors or away
<6, calm	OFF	Indoors	18	39-44	Improvement in health. Fatigue and desire to leave
		Outdoors	32-38	49-54	Improvement in health. Fatigue and desire to leave

present when adverse health symptoms were also present. This was noted as consistent with the research findings of Salt and Hullar (2010) that certain structures in the inner ear are sensitive to infrasound and can be stimulated by low-frequency sounds at levels starting at 60 dBG, well below levels that can be heard. The stimulation is maximal at low background sound levels (e.g., indoors). The authors found that when the wind turbine modulating, pulsing infrasonic levels dropped below 60 dBG (nearest wind turbine OFF), there was improvement in health status.

Worker Exposure and Adverse Health Effects

The authors experienced severe adverse health effects during the study procedures. One author experienced a high degree of irritability within a few minutes of arriving at the home. This was not usual as the author is normally calm. The irritability rapidly progressed to loss of cognitive function to the point where there was an inability to perform routine tasks. Dizziness progressing to apparent vertigo occurred.

The second author experienced headache, loss of appetite, and anxiety and also was not able to perform routine tasks. He was unable to concentrate and had difficulty finishing a thought or sentence. There was a strong desire to leave the area to seek relief.

Overall, there was a loss of ability to perform tasks that were second nature. Simple tasks such as calibrating a meter, which were "automatic" functions due to 30 years of experience, were beyond the ability of the authors for some hours.

A summary of the impacts is that on Day 1 when the winds were high, the authors felt terrible and were debilitated and unable to perform simple tasks. On Day 2, when the winds were lower, the technicians felt a bit better but were still miserable and continued to have difficulty focusing on completing required tasks. On Day 3, with the turbine off, there was improvement in health status, but there remained a desire to leave the area.

In both cases, it took about 7 days for the recovery from the adverse health effects. One author was still experiencing some symptoms 7 weeks later.

Conclusion

Globally, there are reports of adverse health effects correlated with the onset of operations of IWTs (Harry, 2007; Krogh, Gillis, Kowen, & Aramini, 2011; Nissenbaum, 2009; Phipps, Amati, McCoard, & Fisher, 2007; Pierpont, 2009). Pedersen, van den Berg, Bakker, and Bouma (2009) and Pedersen and Waye (2004, 2007) have published peer-reviewed articles regarding the negative effects being reported.

There have been some anecdotal reports from technicians and workers in specialized fields such as electrical and engineering. In addition, there have been several anecdotal reports from other workers such as farmers and operators of heavy equipment (CK, personal communications, 2009 to 2011).

Those working in the environs of IWTs may be at risk for occupational exposure. Technicians and other workers such as farmers and IWT site staff employed for maintenance and other duties may be at risk to symptoms. Others at risk could include truck drivers and other equipment handlers.

This case study report is intended to raise the awareness of occupational health risks. There are unanswered questions about worker exposure. This will require independent research to determine the risks.

Authors' Note

Throughout this article, the term *author(s)* applies to Rand and Ambrose.

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Bios

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Infrasound From Wind Turbines Could Affect Humans

Alec N. Salt[1] and James A. Kaltenbach[2]

Abstract

Wind turbines generate low-frequency sounds that affect the ear. The ear is superficially similar to a microphone, converting mechanical sound waves into electrical signals, but does this by complex physiologic processes. Serious misconceptions about low-frequency sound and the ear have resulted from a failure to consider in detail how the ear works. Although the cells that provide hearing are insensitive to infrasound, other sensory cells in the ear are much more sensitive, which can be demonstrated by electrical recordings. Responses to infrasound reach the brain through pathways that do not involve conscious hearing but instead may produce sensations of fullness, pressure or tinnitus, or have no sensation. Activation of subconscious pathways by infrasound could disturb sleep. Based on our current knowledge of how the ear works, it is quite possible that low-frequency sounds at the levels generated by wind turbines could affect those living nearby.

Keywords

cochlea, hair cells, A-weighting, wind turbine, Type II auditory afferent fibers

Wind Turbines Generate Infrasound

The sounds generated by wind turbines vary widely, depending on many factors such as the design, size, rotor speed, generator loading, and different environmental conditions such as wind speed and turbulence (e.g., Jakobsen, 2005). Under some conditions, such as with a low wind speed and low generator loading, the sounds generated appear to be benign and are difficult to detect above other environmental sounds (Sonus, 2010).

But in many situations, the sound can contain a substantial low-frequency infrasound component. One study (Van den Berg, 2006) reported wind turbine sounds measured in front of a home 750 m from the nearest turbine of the Rhede wind farm consisting of Enercon E-66 1.8 MW turbines, 98 m hub height, and 35 m blade length. A second study (Jung & Cheung, 2008) reported sounds measured 148 to 296 m from a 1.5 MW turbine, 62 m hub height, 36 m blade length. In both these studies, which are among the few publications that report full-spectrum sound measurements of wind turbines, the sound spectrum was dominated by frequencies below 10 Hz, with levels of over 90 dB SPL near 1 Hz.

The infrasound component of wind turbine noise is demonstrated in recordings of the sound in a home with GE 1.5 MW wind turbines 1,500 ft downwind as shown in Figure 1. This 20-second recording was made with a microphone capable of recording low-frequency components. The sound level over the recording period, from which this excerpt was taken, varied from 28 to 43 dBA. The audible and inaudible (infrasound) components of the sound are demonstrated by filtering the waveform above 20 Hz (left) or below 20 Hz (right). In the audible, high-pass filtered waveform, the periodic "swoosh" of the blade is apparent to a varying degree with time. It is apparent from the low-pass filtered waveform that the largest peaks in the original recording represent inaudible infrasound. Even though the amplitude of the infrasound waveform is substantially larger than that of the audible component, this waveform is inaudible when played by a computer's sound system. This is because conventional speakers are not capable of generating such low frequencies and even if they could, those frequencies are typically inaudible to all but the most sensitive unless played at very high levels. It was also notable in the recordings that the periods of high infrasound level do not coincide with those times when the audible component is high.

This shows that it is impossible to judge the level of infrasound present based on the audible component of the sound. Just because the audible component is loud does not mean that high levels of infrasound are present. These measurements show that wind turbine sounds recorded inside a home can contain a prominent infrasound component.

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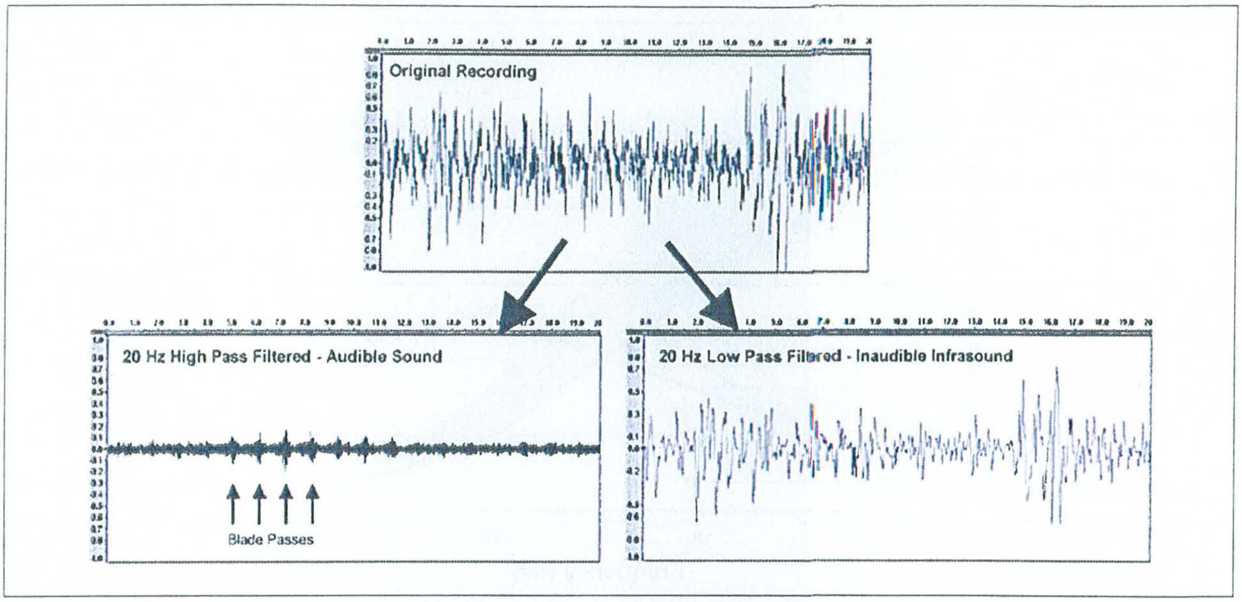

Figure 1. *Upper Panel:* Full-spectrum recording of sound from a wind turbine recorded for 20 seconds in a home with the wind turbine 1,500 ft downwind (digital recording kindly provided by Richard James). *Lower Left Panel:* Result of high-pass filtering the waveform at 20 Hz, showing the sound that is heard, including the sounds of blade passes. *Lower Right Panel:* Result of low-pass filtering the waveform at 20 Hz, showing the infrasound component of the sound

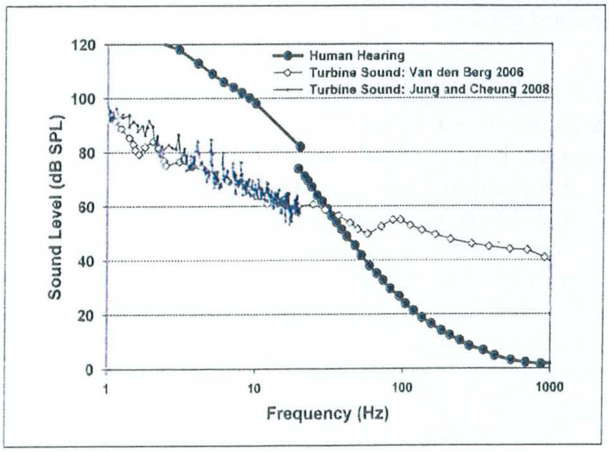

Figure 2. Wide band spectra of wind turbine sounds (Jung & Cheung, 2008; Van den Berg, 2006) compared with the sensitivity of human hearing (International Organization for Standardization, 2003, above 20 Hz; Møller & Pederson, 2004, below 20 Hz). The levels of sounds above 30 Hz are above the audibility curve and would be heard. Below 30 Hz, levels are below the audibility curve so these components would not be heard

Wind Turbine Infrasound Is Typically Inaudible

Hearing is very insensitive to low-frequency sounds, including those generated by wind turbines. Figure 2 shows examples of wind turbine sound spectra compared with the sensitivity of human hearing. In this example, the turbine sound components above approximately 30 Hz are above threshold and therefore audible. The sounds below 30 Hz, even though they are of higher level, are below the threshold of audibility and therefore may not be heard. Based on this comparison, for years it has been assumed that the infrasound from wind turbines is not significant to humans. Leventhall (2006) concluded that "infrasound from wind turbines is below the audible threshold and of no consequence." (p.34) Leventhall (2007) further stated that "if you cannot hear a sound you cannot perceive it in other ways and it does not affect you." (p.135)

Renewable UK (2011), the website of the British Wind Energy Association, quotes Dr. Leventhall as stating, "I can state quite categorically that there is no significant infrasound from current designs of wind turbines." Thus, the fact that hearing is insensitive to infrasound is used to exclude the possibility that the infrasound can have any influence on humans. This has been known for many years in the form of the statement, "What you can't hear can't affect you." The problem with this concept is that the sensitivity of "hearing" is assumed to equate with sensitivity of "the ear." So if you cannot hear a sound then it is assumed that the sound is insufficient to stimulate the ear. Our present knowledge of the physiology of the ear suggests that this logic is incorrect.

The Ear Is Sensitive to Wind Turbine Infrasound

The sensory cells responsible for hearing are contained in a structure in the cochlea (the auditory portion of the inner ear) called the organ of Corti. This organ runs the entire length of the cochlear spiral and contains two types of sensory cells, which have completely different properties. There is one row

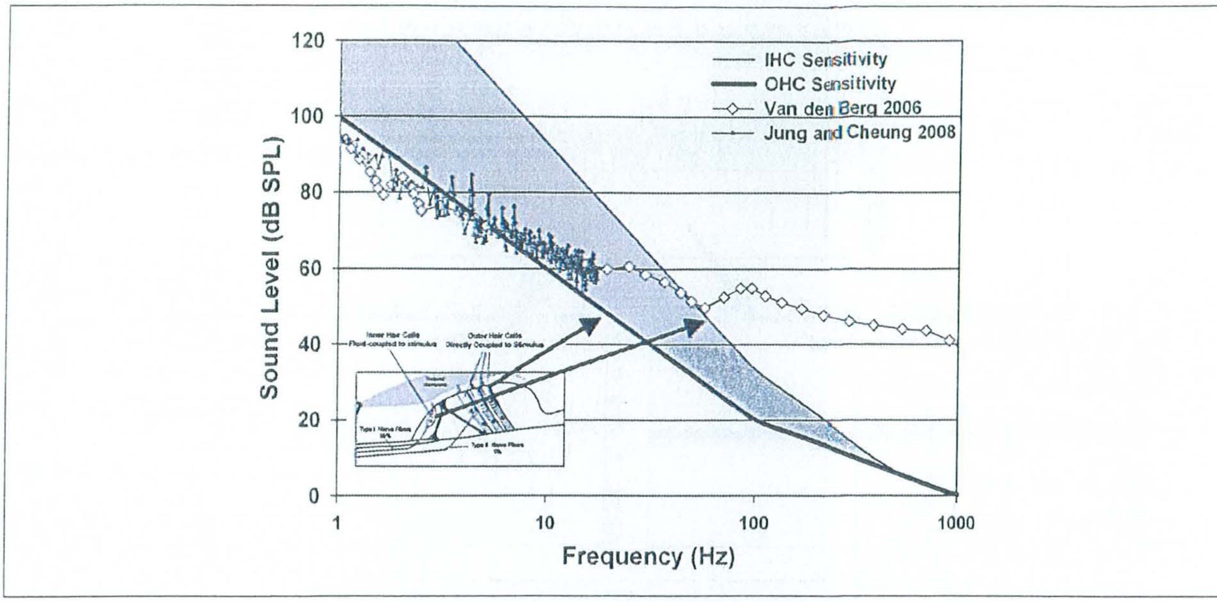

Figure 3. The thin line shows the estimated sensitivity of inner hair cells (IHC) as a function of frequency, which is comparable with the human audibility curve shown in Figure 2 and which is consistent with hearing being mediated by the IHC (based on Cheatham & Dallos, 2001). The thick line shows the estimated sensitivity of the outer hair cells (OHC), which are substantially more sensitive than the IHC. Sound components of the overlaid wind turbine spectra within the shaded region (approximately 5 to 50 Hz) are too low to stimulate the IHC and cannot therefore be heard but are of sufficient level to stimulate the OHC. The inset shows a cross section of the sensory organ of the cochlea (the organ of Corti) showing the locations of the IHC and OHC

of sensory inner hair cells (IHC) and three rows of outer hair cells (OHC) as shown schematically in the inset to Figure 3. For both IHC and OHC, sound-induced deflections of the cell's sensory hairs provide stimulation and elicit electrical responses. Each IHC is innervated by multiple nerve fibers that transmit information to the brain, and it is widely accepted that hearing occurs through the IHC. The rapidly declining sensitivity of hearing at lower frequencies (Figure 2) is accounted for by three processes that selectively reduce low-frequency sensitivity (Cheatham & Dallos, 2001), specifically the properties of middle ear mechanics, from pressure shunting through the cochlear helicotrema and from "fluid coupling" of the inner hair cell stereocilia to the stimulus (reviewed in detail by Salt & Hullar, 2010).

The combined effect of these processes, quantified by Cheatham and Dallos (2001), are shown as the "IHC sensitivity" curve in Figure 3. The last component attenuating low frequencies, the so-called fluid coupling of input, arises because the sensory hairs of the IHC do not contact the overlying gelatinous tectorial membrane but are located in the fluid space below the membrane.

As a result, measurements from the IHC show that they do not respond to sound-induced displacements of the structure but instead their amplitude and phase characteristics are consistent with them responding to the velocity of the stimulus. As stimulus frequency is lowered, the longer cycles result in lower stimulus velocity, so the effective stimulus falls by 6 dB/octave. This accounts for the known insensitivity of the IHC to low-frequency stimuli. For low frequencies, the calculated sensitivity of IHC (Figure 3) compares well with measures of hearing sensitivity (Figure 2), supporting the view that hearing is mediated by the IHC.

The problem, however, arises from the more numerous OHC of the sensory organ of Corti of the ear. Anatomic studies show that the sensory hairs of the OHC are embedded in the overlying tectorial membrane, and electrical measurements from these cells show their responses depend on the displacement rather than the velocity of the structure. As a result, their responses do not decline to the same degree as IHC as frequency is lowered.

Their calculated sensitivity is shown as the "OHC sensitivity" curve in Figure 3. It is important to note that the difference between IHC and OHC responses has nothing to do with frequency-dependent effects of the middle ear or of the helicotrema (the other two of the three components mentioned above). For example, any attenuation of low-frequency stimuli provided by the helicotrema will equally affect both the IHC and the OHC. So the difference in sensitivity shown in Figure 3 arises purely from the difference in how the sensory hairs of the IHC and OHC are coupled to the overlying tectorial membrane.

The important consequence of this physiological difference between the IHC and the OHC is that the OHC are stimulated at much lower levels than the IHC. In Figure 3, the portion of the wind turbine sound spectrum within the shaded region represents frequencies and levels that are too low to be heard, but which are sufficient to stimulate the OHC of the ear.

This is not confined to infrasonic frequencies (below 20 Hz), but in this example includes sounds over the range from 5 to 50 Hz. It is apparent that the concept that "sounds you can't hear cannot affect you" cannot be correct because it does not recognize these well-documented physiologic properties of the sensory cells of the inner ear.

Stimulation of OHC at inaudible, low levels can have potentially numerous consequences. In animals, cochlear microphonics demonstrating the responses of the OHC can be recorded to infrasonic frequencies (5 Hz) at levels as low as 40 dB SPL (Salt & Lichtenhan, in press). The OHCs are innervated by Type II nerve fibers that constitute 5% to 10% of the auditory nerve fibers, which connect the hair cells to the brainstem. The other 90% to 95% come from the IHCs. Both Type I (from IHC) and Type II (from OHC) nerve fibers terminate in the cochlear nucleus of the brainstem, but the anatomical connections of the two systems increasingly appear to be quite different. Type I fibers terminate on the main output neurons of the cochlear nucleus. For example, in the dorsal part of the cochlear nucleus, Type I fibers connect with fusiform cells, which directly process information received from the ear and then deliver it to higher levels of the auditory pathway. In contrast, Type II fibers terminate in the granule cell regions of the cochlear nucleus (Brown, Berglund, Kiang, & Ryugo, 1988). Some granule cells receive direct input from Type II fibers (Berglund & Brown, 1994). This is potentially significant because the granule cells provide a major source of input to nearby cells, whose function is inhibitory to the fusiform cells that are processing heard sounds. If Type II fibers excite granule cells, their ultimate effect would be to diminish responses of fusiform cells to sound. Evidence is mounting that loss of or even just overstimulation of OHCs may lead to major disturbances in the balance of excitatory and inhibitory influences in the dorsal cochlear nucleus. One product of this disturbance is the emergence of hyperactivity, which is widely believed to contribute to the perception of phantom sounds or tinnitus (Kaltenbach et al., 2002; Kaltenbach & Godfrey, 2008). The granule cell system also connects to numerous auditory and nonauditory centers of the brain (Shore, 2005). Some of these centers are directly involved in audition, but others serve functions as diverse as attentional control, arousal, startle, the sense of balance, and the monitoring of head and ear position (Godfrey et al., 1997).

Functions that have been attributed to the dorsal cochlear nucleus thus include sound localization, cancellation of self-generated noise, orienting the head and ears to sound sources, and attentional gating (Kaltenbach, 2006; Oertel & Young, 2004). Thus, any input from OHCs to the circuitry of the dorsal cochlear nucleus could influence functions at several levels.

A-Weighted Wind Turbine Sound Measurements

Measurements of sound levels generated by wind turbines presented by the wind industry are almost exclusively A-weighted and expressed as dBA. When measured in this manner, the sound levels near turbines are typically in the range of 30 to 50 dBA, making wind turbine sounds,

> about the same level as noise from a flowing stream about 50-100 meters away or the noise of leaves rustling in a gentle breeze. This is similar to the sound level inside a typical living room with a gas fire switched on, or the reading room of a library or in an unoccupied, quiet, air-conditioned office. (Renewable UK, 2011)

On the basis of such measurements, we would expect wind turbines to be very quiet machines that would be unlikely to disturb anyone to a significant degree. In contrast, the human perception of wind turbine noise is considerably different. Pedersen and Persson-Waye (2004) reported that for many other types of noise (road traffic, aircraft, railway), the level required to cause annoyance in 30% of people was over 70 dBA, whereas wind turbine noise caused annoyance of 30% of people at a far lower level, at around 40 dBA. This major discrepancy is probably a consequence of A-weighting the wind turbine sound measurements, thereby excluding the low-frequency components that contribute to annoyance. A-weighting corrects sound measurements according to human hearing sensitivity (based on the 40 phon sensitivity curve). The result is that low-frequency sound components are dramatically deemphasized in the measurement, based on the rationale that these components are less easily heard by humans. An example showing the effect of A-weighting the turbine sound spectrum data of Van den Berg (2006) is shown in Figure 4. The low-frequency components of the original spectrum, which resulted in a peak level of 93 dB SPL at 1 Hz, are removed by A-weighting, leaving a spectrum with a peak level of 42 dBA near 1 kHz. A-weighting is perfectly acceptable if hearing the sound is the important factor. A problem arises though when A-weighted measurements or spectra are used to assess whether the wind turbine sound affects the ear. We have shown above that some components of the inner ear, specifically the OHC, are far more sensitive to low-frequency sounds than is hearing. Therefore, A-weighted sounds do not give a valid representation of whether wind turbine noise affects the ear or other aspects of human physiology mediated by the OHC and unrelated to hearing. From Figure 3, we know that sound frequencies down to 3 to 4 Hz may be stimulating the OHC, yet the A-weighted spectrum in Figure 4 cuts off all components below approximately 14 Hz. For this reason, the determination of whether wind turbine sounds affect people simply cannot be made based on A-weighted sound measurements. A-weighted measurements are inappropriate for this purpose and give a misleading representation of whether the sound affects the ear.

Alternatives to A-weighting are the use of full-spectrum (unweighted), C-weighted, or G-weighted measurements. G-weighted measurements use a weighting curve based on the human audibility curve below 20 Hz and a steep cutoff above 20 Hz so that the normal audible range of frequencies is deemphasized. Although the shape of this function is arbitrary

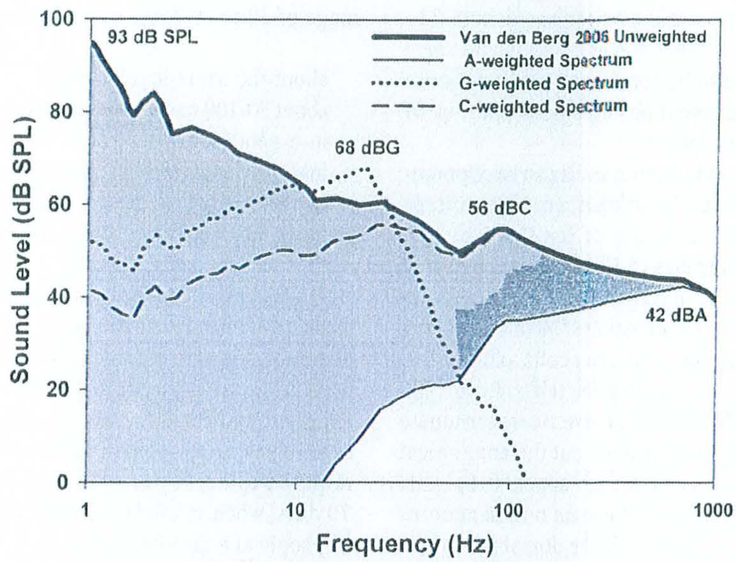

Figure 4. Low-frequency components of wind turbine sound spectrum (below 1 kHz) before and after A-weighting. The original spectrum was taken from Van den Berg (2006). The shaded area represents the degree of alteration of the spectrum by A-weighting. A weighting (i.e., adjusting the spectrum according to the sensitivity of human hearing) has the effect of ignoring the fact that low-frequency sounds can stimulate the OHC at levels that are not heard. Representing this sound as 42 dBA, based on the peak of the spectrum, ignores the possibility that low-frequency components down to frequencies as low as 5 Hz (from Figure 3) are stimulating the OHC. Also shown are the spectra after G-weighting (dotted) and C-weighting (dashed) for comparison

when hearing is not the primary issue, it does give a measure of the infrasound content of the sound that is independent of higher frequency, audible components, as shown in Figure 4. By applying the function to the normal human hearing sensitivity curve, it can be shown that sounds of approximately 95 dBG will be heard by humans, which agrees with observations by Van den Berg (2006). Similarly, by G-weighting the OHC sensitivity function in Figure 3, it can be estimated that sound levels of 60 dBG will stimulate the OHC of the human ear. In a survey of infrasound levels produced by wind turbines measured in dBG (Jakobsen, 2005), upwind turbines typically generated infrasound of 60 to 70 dBG, although levels above and below this range were observed in this and other studies. From Jakobsen's G-weighted measurements, we conclude that the level of infrasound produced by wind turbines is of too low a level to be heard, but in most cases is sufficient to cause stimulation of the OHC of the human ear. C-weighting also provides more representation of low-frequency sound components but still arbitrarily de-emphasizes infrasound components.

Is the Infrasound From Wind Turbines Harmful to Humans Living Nearby?

Our present understanding of inner ear physiology and of the nature of wind turbine sounds demonstrates that low-level infrasound produced by wind turbines is transduced by the OHC of the ear and this information is transmitted to the cochlear nucleus of the brain via Type II afferent fibers. We therefore conclude that dismissive statements such as "there is no significant infrasound from current designs of wind turbines" are undoubtedly false. The fact that infrasound-dependent information, at levels that are not consciously heard, is present at the level of the brainstem provides a scientific basis for the possibility that such sounds can have influence on people. The possibility that low-frequency components of the sound could contribute both to high annoyance levels and possibly to other problems that people report as a result of exposure to wind turbine noise cannot therefore be dismissed out of hand.

Nevertheless, the issue of whether wind turbine sounds can cause harm is more complex. In contrast to other sounds, such as loud sounds, which are harmful and damage the internal structure of the inner ear, there is no evidence that low-level infrasound causes this type of direct damage to the ear. So infrasound from wind turbines is unlikely to be harmful in the same way as high-level audible sounds.

The critical issue is that if the sound is detected, then can it have other detrimental effects on a person to a degree that constitutes harm? A major complicating factor in considering this issue is the typical exposure duration. Individuals living near wind turbines may be exposed to the turbine's sounds for prolonged periods, 24 hours a day, 7 days a week for weeks, possibly extending to years, although the sound level will vary over time with varying wind conditions. Although there have been many studies of infrasound on humans, these have typically involved higher levels for limited periods (typically of up to 24 hours). In a search of the literature, no studies were found that have come close to replicating the long-term exposures to low-level infrasound experienced by those living near wind turbines. So, to date, there are no published studies showing that such prolonged exposures do not harm humans. On the other hand, there are now numerous reports (e.g., Pierpont, 2009; Punch, James, & Pabst, 2010), discussed extensively in this journal, that are highly suggestive that individuals living near wind turbines are made ill, with a plethora of symptoms that commonly include chronic sleep disturbance. The fact that such reports are being dismissed on the grounds that the level of infrasound produced by wind turbines is at too low a level to be heard appears to totally ignore the known physiology of the ear. Pathways from the OHC to the brain exist by which infrasound that cannot be heard could influence function. So, in contrast, from our perspective, there is ample evidence to support the view that infrasound could affect people, and which justifies the need for more detailed scientific studies of the problem. Thus, it is possible that people's health could suffer when turbines are placed too close to their homes and this becomes more probable if sleep is disturbed by the infrasound. Understanding these phenomena may be important to deal with other sources of low-frequency noise and may establish why some individuals are more sensitive than others. A better understanding may also allow effective procedures to be implemented to mitigate the problem.

We can conclude that based on well-documented knowledge of the physiology of the ear and its connections to the brain, it is scientifically possible that infrasound from wind turbines could affect people living nearby.

Declaration of Conflicting Interests

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The Problems With "Noise Numbers" for Wind Farm Noise Assessment

Bob Thorne

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The Problems With "Noise Numbers" for Wind Farm Noise Assessment

Bob Thorne[1]

Abstract

Human perception responds primarily to sound character rather than sound level. Wind farms are unique sound sources and exhibit special audible and inaudible characteristics that can be described as modulating sound or as a tonal complex. Wind farm compliance measures based on a specified noise number alone will fail to address problems with noise nuisance. The character of wind farm sound, noise emissions from wind farms, noise prediction at residences, and systemic failures in assessment processes are examined. Human perception of wind farm sound is compared with noise assessment measures and complaint histories. The adverse effects on health of persons susceptible to noise from wind farms are examined and a hypothesis, the concept of heightened noise zones (pressure variations), as a marker for cause and effect is advanced. A sound level of LAeq 32 dB outside a residence and above an individual's threshold of hearing inside the home are identified as markers for serious adverse health effects affecting susceptible individuals. The article is referenced to the author's research, measurements, and observations at different wind farms in New Zealand and Victoria, Australia.

Keywords

wind farms, human perception, noise

Wind Farms Are a Unique Source of Noise

Wind farms and wind turbines are a unique source of sound and noise. The noise generation from a wind farm is like no other noise source or set of noise sources. The sounds are often of low amplitude (volume or loudness) and are constantly shifting in character ("waves on beach," "rumble-thump," "plane never landing," etc.). People who are not exposed to the sounds of a wind farm find it very difficult to understand the problems of people who do live near wind farms (Thorne, 2007). Some people who live near wind farms are disturbed by the sounds of the farms, others are not. In some cases adverse health effects are reported, in other cases such effects do not appear evident. Thus, wind farm noise is not like, for example, traffic noise or the continuous hum from plant and machinery. Wind turbines such as those proposed are large noise sources relative to dwellings, and like aircraft, sound emissions are transmitted via the roof and windows. Noise barriers at ground level are generally ineffective in screening or mitigation such sound (Thorne, 2011).

Wind has audible and subaudible characters. That is, measurement of wind sound will always present sound levels in the audible, low-frequency, and infrasonic frequencies. Sound in the low frequencies and infrasound frequencies can be heard if the sounds are loud enough. The sounds, however, may be perceptible rather than heard at relatively lower levels of "loudness."

Evidence produced in New Zealand concerning the West Wind and Te Rere Hau wind farms indicate that the adverse effects of wind farm noise are well documented. West Wind has recorded 906 complaints over a 12-month period. Te Rere Hau has recorded 378 complaints over an 11-month period. Waubra (Victoria, Australia) has a less well documented complaint history but, as recorded in this article, sufficient to identify issues.

Wind farm sound analysis presents three distinct issues:

- The identification of sound that can be directly attributed to the sound of the wind farm/turbines, measured as a background sound level, compared with the sound of the ambient environment without the presence of the wind turbines
- The sound of any special audible characteristics of the wind farm/turbines, such as distinct tonal complexes and modulation effects (amplitude and frequency) that may affect human health through sleep disturbance, for example
- The presence of any sound characteristics that may affect human health

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Sound from modern wind turbines is primarily due to turbulent flow and trailing edge sound, mechanical sound, and variations in infrasound (air pressure variations). Sound character relates to blade characteristics, blade/tower interaction, and mechanical noise and can be grouped into four main bands. The sound can be characterized as being impulsive and broadband, audible and inaudible (infrasonic):

- Infrasound below, 20 Hz (perceptible, normally inaudible)
- Low frequencies, 20 to 250 Hz
- Mid frequency, 250 to 2,000 Hz (broadly, although the higher level could be 4,000 Hz)
- High frequency, 2,000 to 20,000 Hz

Not all these frequencies can be heard by a person with "normal" hearing, as hearing response is unique to an individual and is age dependent as well as work and living environment dependent. It is important to note that infrasound can be "audible" to people with sensitive hearing (Thorne, 2011). Evidence briefly summarized in this article allows the conclusion that there is the potential for adverse health effects for individuals due to wind farm activity while living in their residences and while working on their farms within 3,500 meters of large-scale turbines. Wind farm activity that causes adverse health effects such as sleep disturbance, anxiety, stress, and headaches is a health nuisance, is objectionable, and is unreasonable.

Research indicates that "ordinary" wind has a laminar or smooth infrasound and low-frequency flow pattern when analyzed over short periods of time. Wind farm activity appears to create a "pulsing" infrasound and low-frequency pattern. These patterns are illustrated in sonograms in this article. The hypothesis derived from my research is that wind farm sound has an adverse effect on individuals due to this pulsing nature as well as audible noise due to the wind turbines. These effects may be cumulative.

The Problems With "Noise Numbers" for Wind Farm Noise Assessment

Analysis of "single-value" A-weighted wind farm background levels in the presence of ambient background levels (the real world) is extremely difficult to impossible. This observation is made on the basis of 5 years of monitoring wind turbines at different locales under widely different weather conditions. Figure 1 illustrates the issue: there are the separate sets of sound sources—local ambient, the turbines, and distant sources. It is not possible to separate out the contribution of each source once it is recorded as a single-value (e.g., the "background LA95" sound level or "time-average LAeq" sound level) at a specific location, such as a residence.

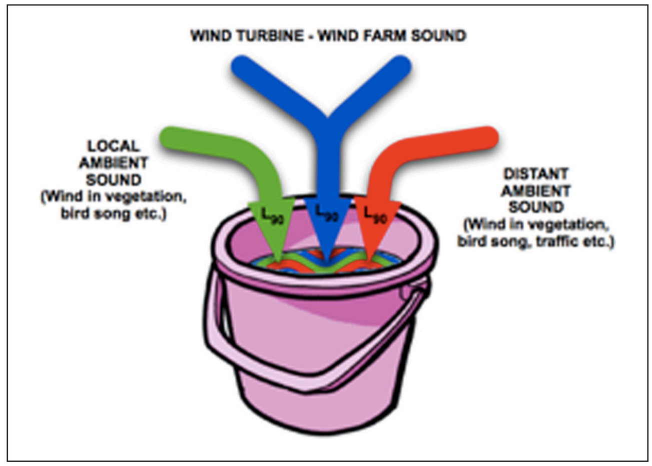

Figure 1. "Bucket of mixed sound" from different sources

By way of example, pour a glass of milk (noise specifically from wind farm activity) into a glass of water (the ambient sound around a residence). Add some extra water for distant sound (wind in trees, distant water pumps, etc.) that affects the background. Now remove the milk. Difficult? Impossible. The three components are completely intermingled. Unfortunately, the example holds true for whatever combination of "single-value" acoustical descriptors are used to describe wind farm mixed with ambient sound levels. A practical alternative is to identify a set of sounds that are specific to the wind farm that are not a characteristic of the receiving environment and reference these sounds. The levels are recorded as, for example, unweighted (*Z*) sound levels in third octave or 1/12 octave bands. Still difficult, but not impossible.

Obviously, loud levels of sound from a wind farm in excess of LAeq 35 dB may be measurable but still very difficult to prove as being the source of sound when mixed into sound from vegetation (wind in trees, for example).

Conversely, it is easy for people to hear wind farm noise within "ordinary" ambient sound.

It is on this fundamental issue that any standard or condition requiring a wind farm to comply with a specific compliance level will fail. The only possible way is to turn the turbines off, measure the ambient levels, turn the turbines on, measure the wind farm and ambient sound levels together, assess the variation and then come to some decision as to compliance. This procedure only applies to an audit process and fails, of course, if noise complaints are being investigated when the wind farm noise and the ambient sound are completely mixed together and the wind farm sound is not clearly dominant.

The problems with understanding the potential effects of the wind farm start with the sound level predictions often used to assess compliance against some form of guideline or legislation.

Prediction of Wind Farm Sound Levels

Sound level predictions are not "accurate"; they do not present the sound levels that will be heard at any one location at any one time. Rather, a prediction is a mathematical equation referenced to a lot of assumptions and uncertainties. Because of this, the predicted levels are also "uncertain." The art in prediction is to identify all the assumptions and uncertainties to present a realistic assessment under realistic daily conditions. This is extremely difficult to do and cannot be done with certainty using simple prediction methods such as ISO 9613-2:1996 *Acoustics-Attenuation of sound during propagation outdoors; Part 2 General method of calculation*.

Conversely, the prediction method can be used to provide an indication of expected sound levels over a long term of 12 months, for example.

To gain an initial understanding of the potential noise levels from a wind farm, it is common practice to prepare a noise map of the locality based on the 9 m/s turbine sound power information and residents living in the locale. Noise predictions do not tell the whole story, however. Meteorological conditions, wind turbine spacing, and associated wake and turbulence effects, vortex effects, turbine synchronicity, tower height, blade length, and power settings all contribute to sound levels heard or perceived at residences. In addition to this, the method of prediction has what is known as "uncertainty."

That is, the predicted values are given as a range, ±3 dB(A) at 1,000 meters for the most common prediction method with the predicted value being the "middle" of the range. The uncertainty increases with distance and the effect of two or more turbines operating in phase with a light/strong breeze blowing toward a residence. A variation of 6 to 7 dB(A) can be expected under such adverse conditions. Thus, on any given day the wind farm background LA95 or "source" time-average (LAeq) sound levels—assuming the wind farm is operating—could vary significantly in comparison with the predicted sound level. This is without the additional effect of any adverse wind effects or weather effects such as inversions.

A typical view from a residence toward the nearest towers approximately 1,800 to 2,200 meters to the south is shown in Photo 1. This shows the turbines side-on to the residence. The side-on angle of the blades allows the effect known as vortex shedding affect the residence. If the blades are full-on, as would be the case with a southwest breeze, the residence is affected by cumulative sound as well as wake and turbulence effects. The effects are potentially more noticeable on the land as there is no screening effect from the pressure changes that can occur. The wake effects are observable when the wind blows from one turbine to the other; the effects are not dependent on the direction of the turbines to the observer. The effect of the turbines at night can be seen in Photo 2.

Photo 1. Wind turbines as seen from a residence

Photo 2. Warning lights and visual effects, a local wind farm

Shepherd and Hubbard (1986) suggest that turbines "shift" from line source to point source decay characteristics at a separation distance of approximately 900 meters. Thus, a wind farm can be considered as a discrete line source consisting of multiple sources that can be identified by distance and spacing (blade swish, blade past tower, wake and turbulence interference effects, and vortex shedding). These sources are identifiable (see Photos 3 and 4). The imaging in Photo 3 shows the different sound levels from the blades of the two turbines.

The pattern in Photo 4 shows clearly the vortex shedding from the blade on the downstroke. The dominant source of sound is from the blades with an overall sound variation in the order of 2 dB(A). The measurements are taken at approximately 150 meters behind the turbine. Frequencies below 300 Hz can also be measured.

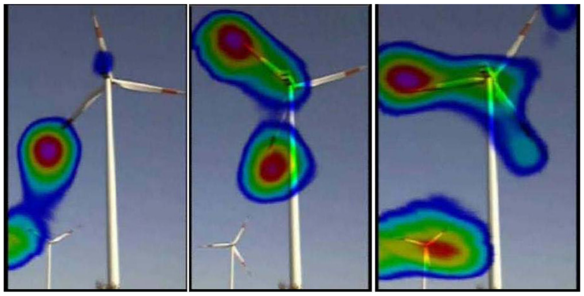

Photo 3. Acoustic photograph of sound sources from two turbines
Source. Acoustic Camera, "Multiple sources wind turbines 300Hz – 7kHz. avi" by permission from HW Technologies, Sydney.

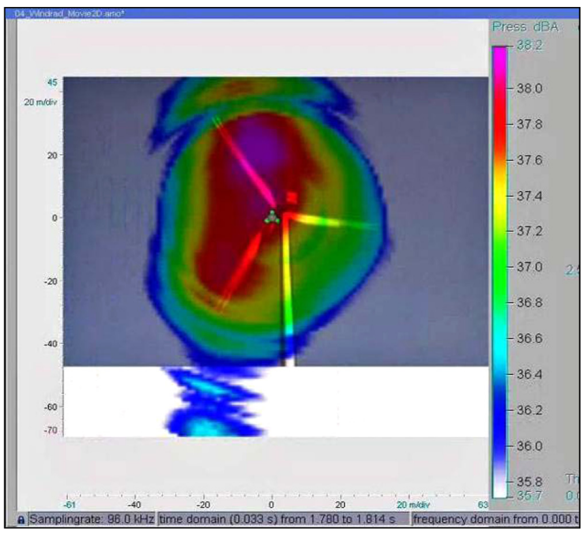

Photo 4. Acoustic photograph of sound sources from a turbine
Source. Acoustic Camera, by permission from HW Technologies, Sydney.

Wake effects are always created as highly turbulent air leaving a turbine interacts with lower speed air. A major wind turbine manufacturer recommends a distance of at least 5 rotor diameters between the wind turbines. Wake effects with pockets of lower speed air are present within 3 rotor diameters downwind and mostly dissipated at a distance of 10 rotor diameters. If a second turbine is situated within 10 rotor diameters of the first turbine, the blades of the second turbine can suddenly enter into a pocket of slower air in the wake caused by the first turbine. I. Shepherd (personal communication, 2010) concludes that increased sound levels will occur and the propagation distance in meters to a defined "criterion" or sound level can be calculated.

The vortex travels downwind in the form of a helix, rotating about its axis with each vortex replacing the previous one in space at approximately 1-second intervals—sometimes more, sometimes less depending on the speed of rotation and number of blades. The practical effect is to create heightened noise zones (HNZs).

It is hypothesized that an HNZ is the combined effect of directional sound and vibrations (wave trains) from the towers, the phase between turbines' blades, lensing in the air or ground, and interference between turbines' noise (audible) and vibration causing very localized patches of heightened noise and/or vibration. The wave train travels in time and the heightened peaks and troughs create a HNZ at an affected residence. The effect has been consistently measured at a residence 1,400 to 2,000 meters downwind from a row of turbines. The HNZ is directly affected by the design and operation of the wind farm (location and type of turbines, phase angles between blades) and wind conditions. These variables and the effects of wind shear are confounding factors that must also be taken into account when predicting the potential for noise from a wind farm.

The HNZs can be small in extent—even for low frequencies and infrasound—leading to turbine sounds "disappearing" and "appearing" in areas spaced only a few meters apart. The concept of HNZ goes a long way in explaining the problem of wind farm noise and its variability on residents. The other factor is the variability of the background sound levels as affected within the HNZs. The turbine sound levels have the effect of lifting the background (when in phase or acting together). The background drops when in the trough between the crest of the HNZ levels. However, this effect can change quite quickly depending on wind direction, temperature conditions, and turbine activity.

In summary, the prediction of wind farm sound levels at a receiver depends on a whole range of different assumptions and uncertainty, for example:

- The true sound power level of the turbine(s) at the specified wind speed
- The reduction in sound level due to ground effects
- The increase or reduction in sound level due to atmospheric (meteorological) variations and wind direction
- The variation due to modulation effects from wind velocity gradient
- Increase and reduction in sound levels due to wake and turbulence modulation effects due to turbine placement and wind direction
- Increased sound levels due to synchronicity effects of turbines in phase due to turbine placement and wind direction
- Building resonance effects for residents inside a dwelling

Wind farm noise level predictions can therefore be considered as only approximations of sound levels and cannot be given any weight other than this. The reasons are due to the highly complex nature of the sound created by each individual turbine and the cumulative effects of a number of turbines. Unfortunately, noise predictions are often taken as

Table 1. Average LA95 Sound Levels Recorded at Residence (Levels Rounded)

Date	LA95 Day, 7 a.m. to 6 p.m.	LA95 Evening, 6 p.m. to 10 p.m.	LA95 Night, 10 p.m. to 7 a.m.
October 15	—	35	—
October 16	37	40	32
October 17	34	32	36
October 18	29	26	27
October 19	29	29	25
October 20	34	31	29
October 21	34	29	31
October 22	30	31	33
October 23	32	25	36
October 24	33	35	26
October 25	38	—	—

being 100% true by naïve approving authorities. This sense is often bolstered by consultants claiming their predictions are "conservative" when in fact they are nothing of the kind. A conservative set of predictions includes all assumptions and uncertainties for different times of day/night, different weather/wind conditions, and the cumulative influence of the whole wind farm.

The situation becomes worse when the predicted levels are referenced to background sound levels as is the case with many wind farm guidelines, standards, and compliance requirements. These conditions are often called "background-plus" criteria where the compliance levels are determined against measured or predicted background sound levels.

Background Sound Levels

Background sound levels are the cornerstone of many acoustical standards dealing with wind farm noise. But what are background levels and how are they measured? Are they constant? Can anyone say with certainty that a background level measured at one location will be the same as in another nearby location? Does the wind affect the levels of background sound? How can wind turbine sound be identified in background sound?

These questions are answered by observations for a case study, "The Dean Report" (Thorne, 2010), taken at two different times in 2009 under different weather conditions. Although the residence is affected by wind turbine noise, a series of ambient and background sound levels were recorded in order to gain an indication of the levels within the locale. Ambient recordings were taken over the period October 15-30, 2009. Ambient A-weighted sound levels were measured generally in accordance with Australian Standard AS1055.1:1997. The ambient sound levels were recorded at 10-minute intervals over a 10-day period (see Table 1). Weather data (wind speed and direction, temperature, and humidity) were recorded for the same time period. Nighttime is recorded as from 10 p.m. the previous day to 7 a.m. on the nominal day.

Table 1 shows the wide range in sound levels at the residence. The levels, at approximately 2,000 meters from the turbines, show the impossibility of determining when or if the wind farm is exceeding a background level of 35 or 40 dB(A). It can be inferred that for some of the time the wind farm is in compliance but at other times it might not. The situation becomes more difficult if there is sufficient breeze to cause a significant lift in background levels.

Finally, if compliance depends on the presence—or not—of audible tones or modulation, then determination becomes near impossible without people to describe the character of the sound. Due to the nature of an operational turbine, modulation is a continuous feature of the wind farm under normal operational conditions—but the sound may not always be audible. In this case the residence is not occupied and the character of the sound—audible modulation in particular—cannot be determined "all the time" on the basis of personal physical observation. The background sound levels are often adjusted for special audible characteristics such as modulation or tonality. Modulation can, however, be determined from sound recordings from a calibrated sound level meter at a relevant time and place investigating the sounds of the wind farm.

The important compliance issue is, "How can special audible characteristics be measured in real time." The answer is, "With difficulty." Either of these two criteria requires full-time real-time monitoring in order for compliance to be proven or not proven at any affected residence.

Sound propagation varies significantly under different wind conditions and influences both the background levels and the character of the sound, especially:

- When there is a strong breeze at the turbines but no or little breeze at the residence
- When the prevailing breeze is blowing from the wind farm to the residence
- Under conditions of cool, clear evenings/nights/mornings when a mist (inversion) covers the ground

This latter condition is sometimes (in Australia) called the "van den Berg effect." It is a common condition and is explained further in this article. My own observations at operational wind farms at distances of around 1,400 meters show that sound levels are higher under calm or inversion conditions (cold clear night) at the observer than under unstable conditions (e.g., light breeze during the day). Sound levels under inversion conditions are often louder and clearer at observer locations. The effects of temperature inversion in the locale supports inversion (fog) conditions and enhanced and elevated sound levels at the residences are expected. Under stable or inversion conditions sound levels do not decay as quickly compared with unstable conditions.

Thus, the real sound levels from the wind farm may vary considerably within any 24-hour period, due to weather conditions. As with special audible characteristics, measurement

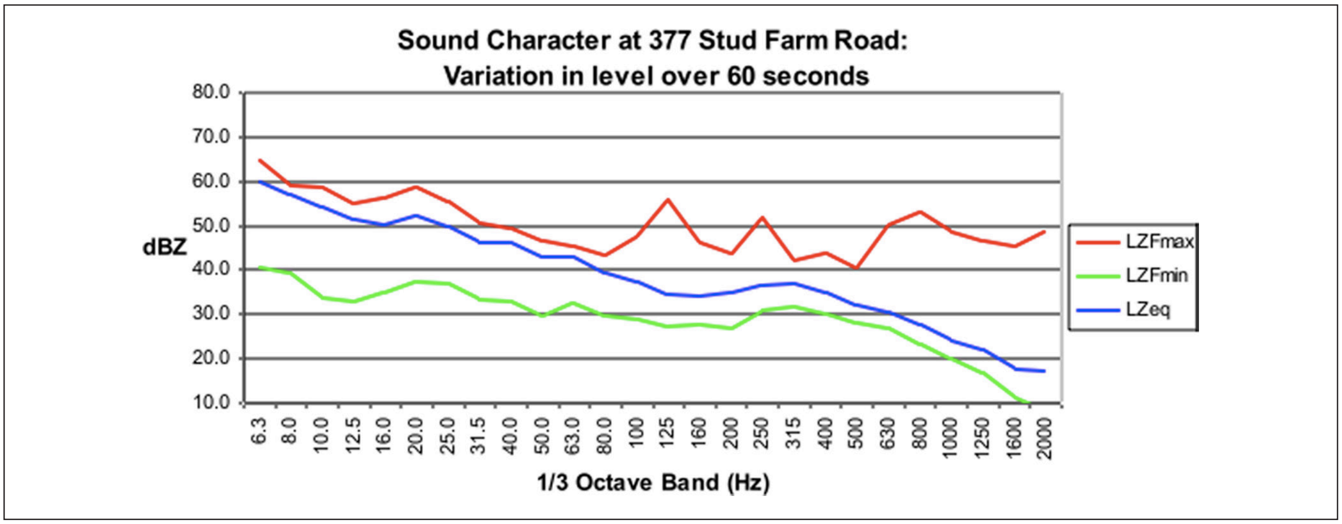

Figure 2. Variation in sound character over 60 seconds

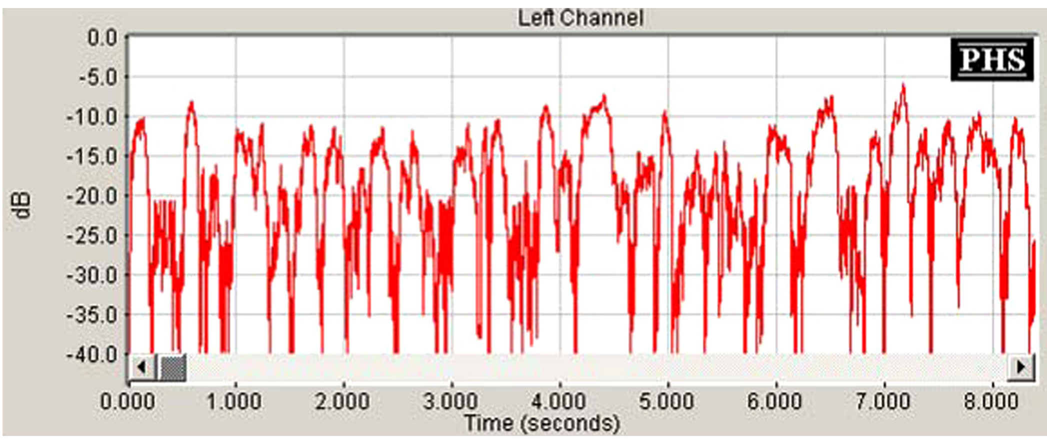

Figure 3. Pulse pattern from an operational wind farm

of wind farm noise for compliance requires full-time real-time monitoring in order for compliance to be proven or not proven at any affected residence. This applies to both audible and inaudible sound.

Audible Sound Character

The operation of the turbines to the southwest of the residence can be clearly heard at the residence. The sound on Thursday evening at 9:40 p.m., October 15, 2009, can be described as a steady rumble with a mixture of rumble-thumps. Wind in the trees or vegetation is not intrusive. Figure 2 presents the variation between maximum, minimum, and average (Leq) unweighted sound levels. Unweighted ("*Z*" weight sound levels) are referenced to assess the audibility of the sound.

In 60 seconds the sound character varies regularly by more than 20 dB; this level of variation will be audible. The generally accepted variation for a clear sense of audibility is 3 dB. Far finer detail is available by analyzing the sound into amplitude variation over the 60 seconds (see Figure 3). The figure shows the regular pulsing or modulation that is typical of blade passing the tower.

The background ambient sound levels for the assessment in Figure 2 references ambient levels recorded at the residence when the turbines were not operating. To confirm that a sound is audible to a person of "normal" hearing, an analysis of broadband sound such as the sounds recorded on the Thursday and illustrated in Figure 2 can be further analyzed for audibility. The higher the orange line is above the green line in Figure 4, the more clearly the signal can be heard. As a guide, a 3 dB shift can be readily heard. The sound is also compared against the hearing threshold level for a "normal" person.

From just this short survey it can be concluded that the wind farm was in noncompliance with a 40 dB(A) background criterion that includes a penalty for special audible characteristics. Sound from wind farms can be easily heard

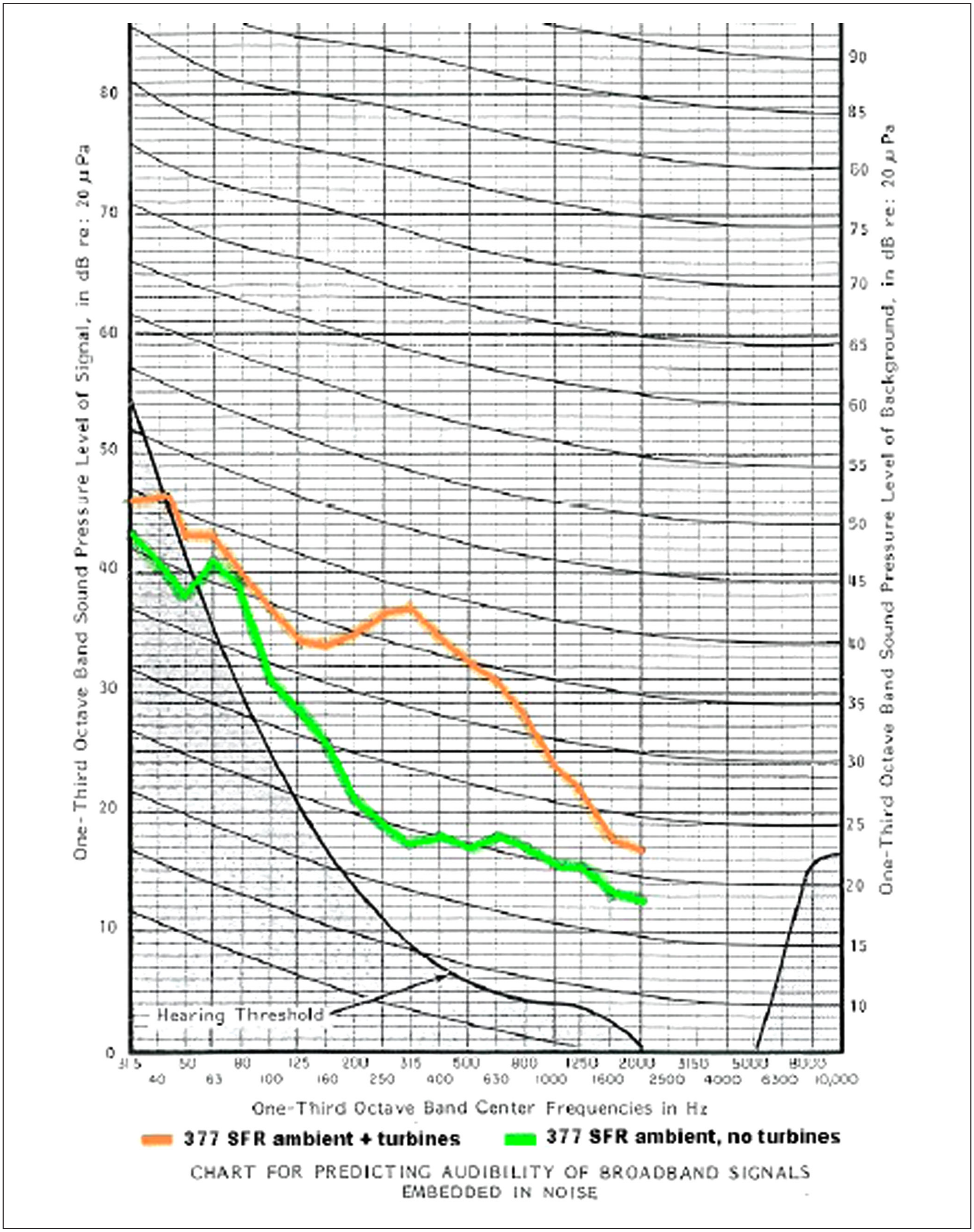

Figure 4. Audibility of wind turbines at a residence

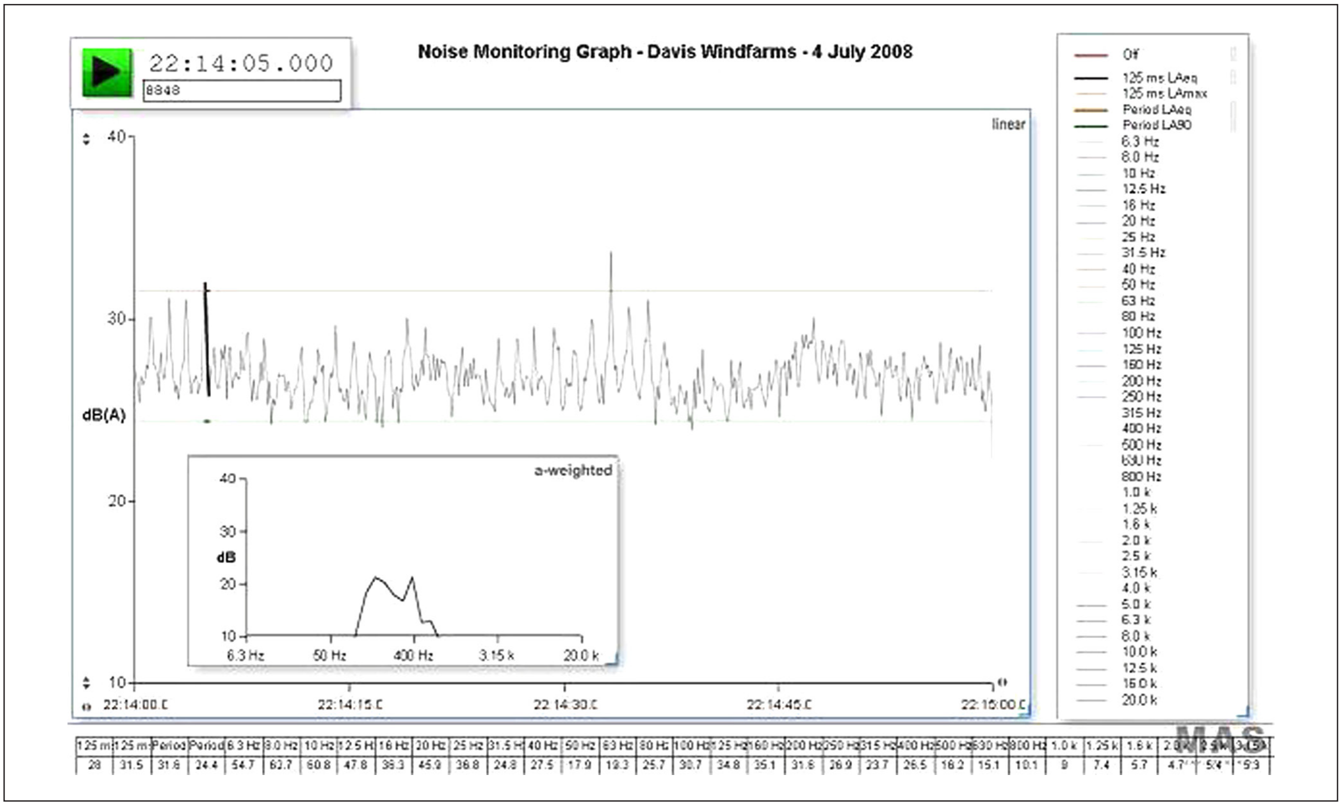

Figure 5. Sound of wind turbines at 930 meters, inside residence

at distances of 2,000 meters; such sound was measured as the background level over the range 29 to 40 dB(A) with conditions of calm to light breeze. The sound was modulating and readily observed and recorded. The sound can be defined as being both unreasonable and a nuisance. But in this case the sound is also causing adverse health effects to exposed residents. It is concluded that the reason for this is the effects of audible nuisance noise and infrasound.

Low-Frequency Sound and Infrasound

The issue of low-frequency sound and infrasound has been a controversial topic for many years. Figure 5 illustrates audible sound as well as both low-frequency and infrasound as heard inside a bedroom approximately 930 meters from a set of wind turbines. The modulating character of the sound is clearly defined in the first 5 seconds as a pattern of three spikes. The chart shows that low levels of sound are clearly audible inside a dwelling. The interior level for the 60 seconds is LAeq 31.6 dB. There are clear and distinctive audible, low-frequency, and infrasound levels. The residents (the United Kingdom) have vacated the dwelling.

In the Waubra case study, the sounds of the wind turbines were recorded at the residence and in the locale. Figures 6 and 7 illustrate the sound levels and character of the sound, including ambient wind, outside the residence. The initial survey was only for the time period 19:40 October 15, 2009, to 01:40 October 16, 2009. The wind dropped after 20:10 and the sound levels decreased.

The outdoor sound levels indicate fluctuating background (LA90, LA95) sound levels with significant variations in the “time-averaged” level, LAeq. The variations are not unusual. The LA95 level for the time period is 33.9 dB(A). The overall sound character shows slight variation between the time-averaged level, LZeq, and the maximum levels, LZmax, in each third octave band. The variation, however, is in the order of 6 dB or more in each band and this is audible.

The initial survey recorded the sound levels inside the residence. Figures 8 and 9 illustrate the sound levels and character of the sound, including ambient wind.

Figure 8 represents a time slice for the beginning of the survey when the sound of the turbines was audible outside. The inside background (LA90, LA95) sound levels are compared with the `time-averaged’ level, LAeq. The consistency in level is not unusual for inside a home. The LA95 level for the time period is 17.4 dB(A). The average level is LAeq 32.5 dB. At 8 p.m., the wind dropped and the sound levels within the home decreased, with an average sound level of LAeq 18 dB, just above the background level.

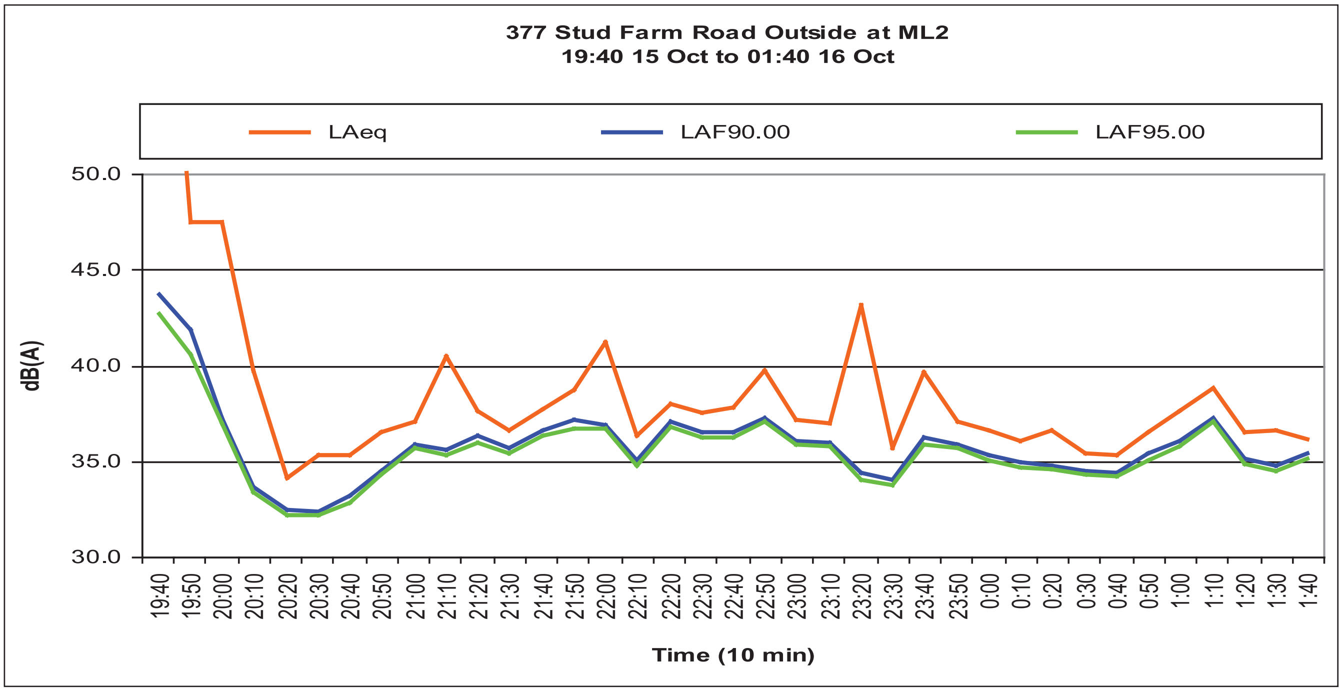

Figure 6. Outdoor sound levels for the initial survey

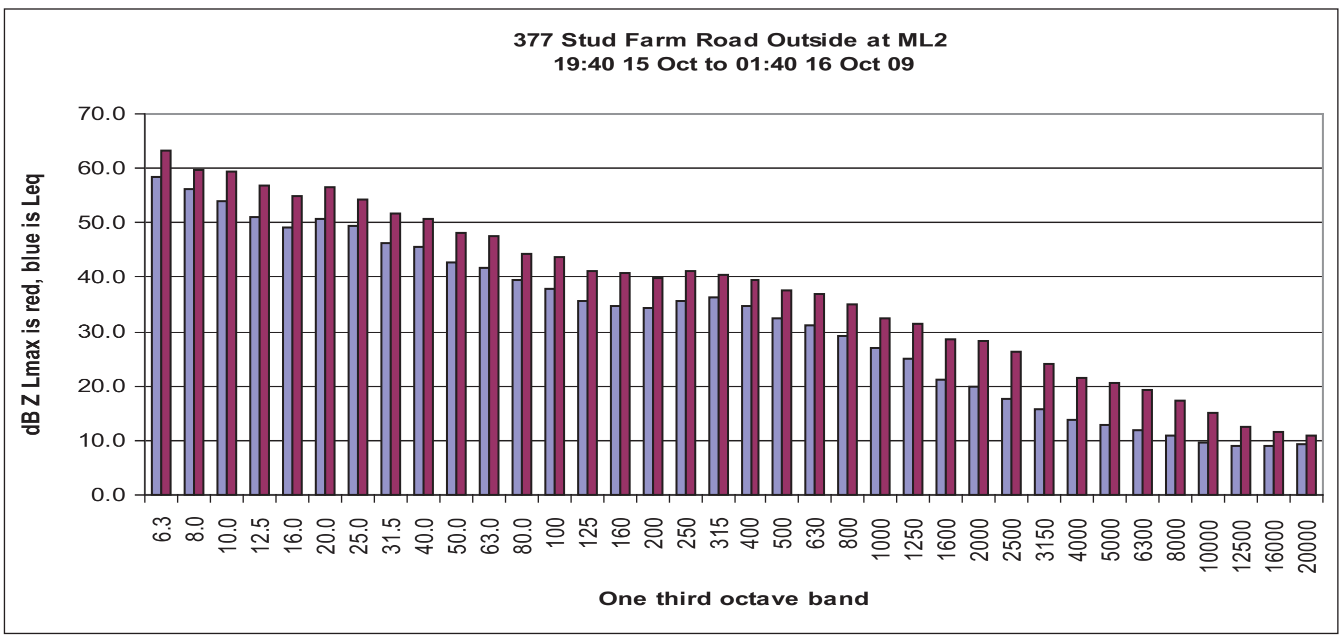

Figure 7. Outdoor sound character for the initial survey

The caution here is that sound levels vary significantly over very short (10 minutes, for example) periods of time. Thus, an assessment on an average longer-term level (Figure 8) may not truly represent the short-term effect of varying sound character (Figure 9).

The observation from Figure 9 is that the overall sound character shows substantial variation between the minimum level, LZmin, and the maximum levels, LZmax, in each third octave band. The variation is significant above 20 Hz because this is when the difference in sound levels becomes audible. The levels show the failure of A-weighted statistical levels in presenting the true sound character.

Sound levels were recorded inside the residence main bedroom over the time period 9:12 a.m. October 12, 2009, to 10:02 a.m. October 13, 2009 (see Figure 10). The wind farm was in operation at this time. The sound levels were

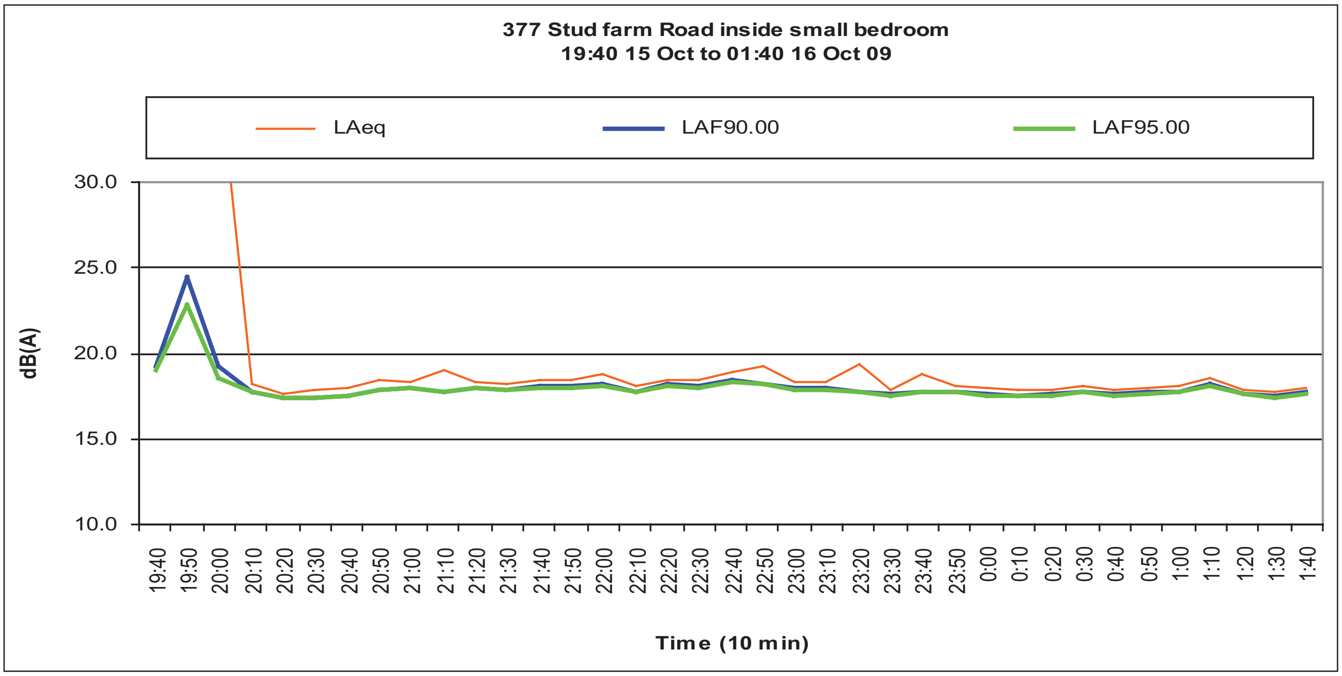

Figure 8. Indoor sound levels for the initial survey

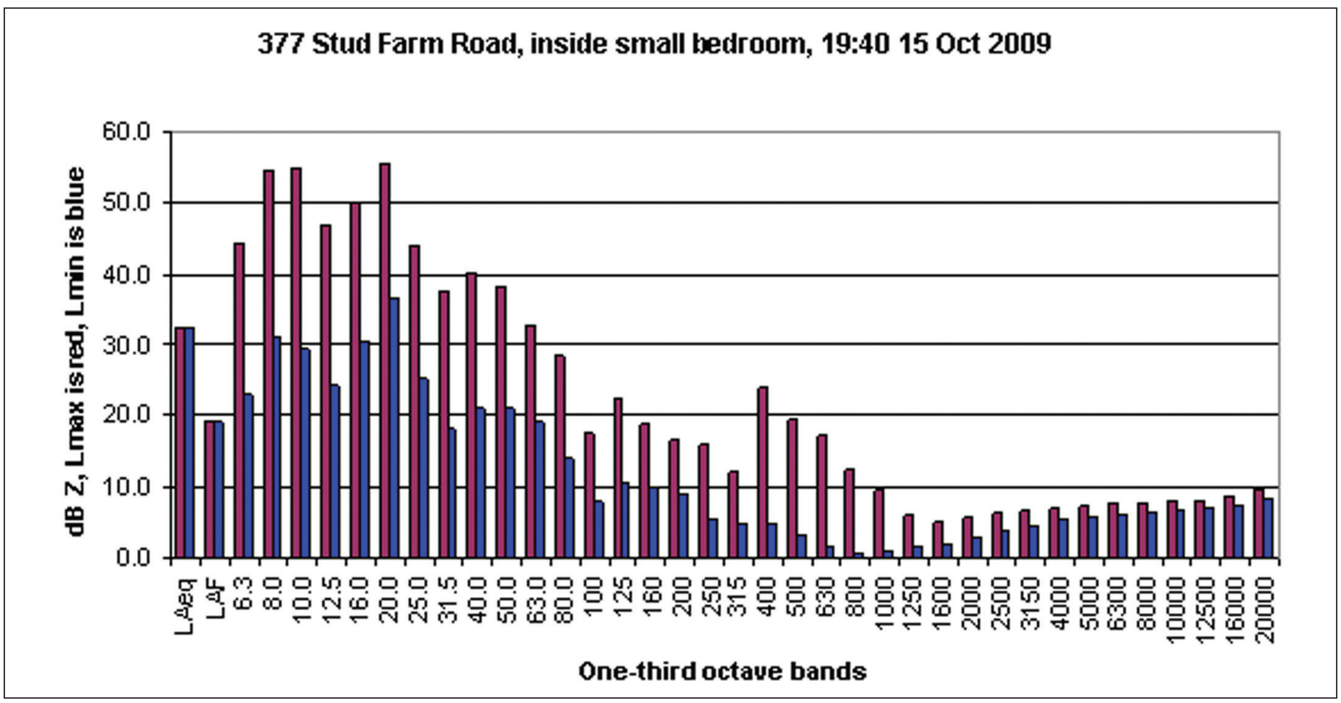

Figure 9. Indoor sound character for the initial survey

recorded in third octave bands every 30 seconds and the average levels for this time period are presented in the following. The SVAN sound level meter is able to record to a lower frequency compared with the Larson Davis 831 meter.

The character of the sound levels is similar to the time-average level *outside*, but there is significant variation between the levels in the two bedrooms. The point is to show that rooms in a residence can and will show significantly different characteristics. What may be inaudible or not perceptible in one room can be easily heard or perceived in another room on the same side of the house. The other concern is that the main bedroom appears to have little sound reduction from outside to inside. The recorded levels are with turbine activity and it is concluded that ambient and wind farm activity will be audible within the bedrooms.

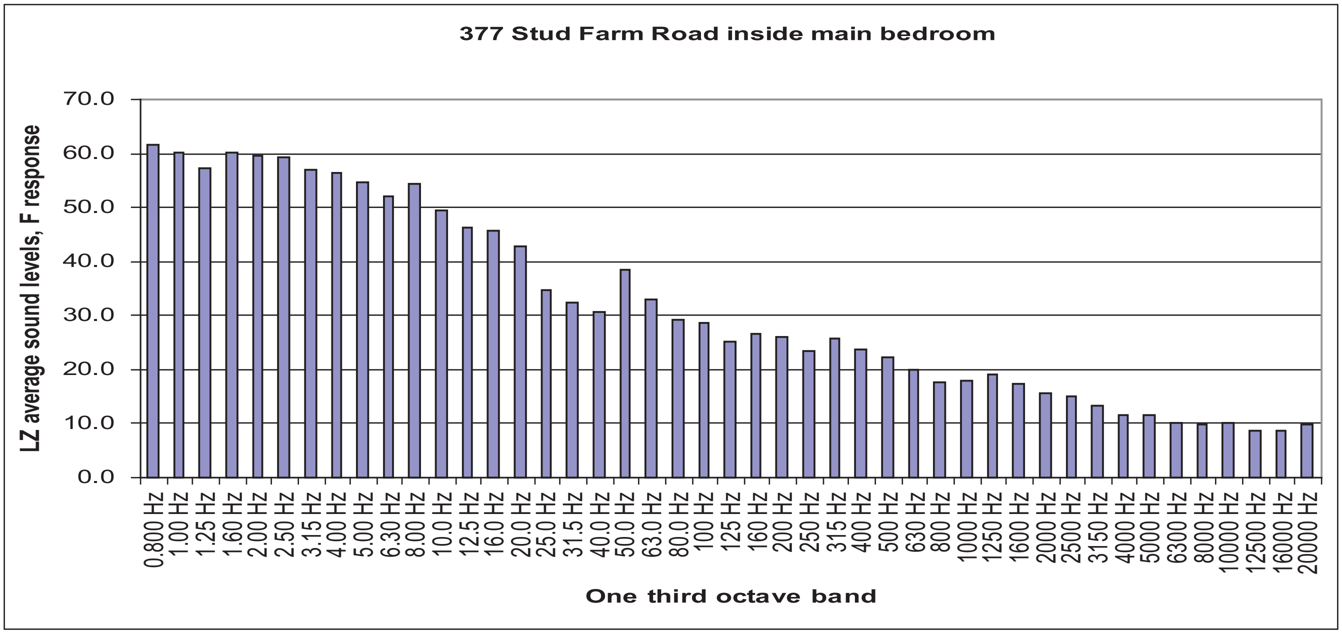

Figure 10. Indoor sound character (main bedroom)

Sonograms are presented to illustrate specific locations with and without turbine activity. The sonograms illustrate the presence of turbines even though the activity may not be audible. Different time segments are used to illustrate the effects. The important features are the following:

- The significant amount of sound energy in the low-frequency and infrasonic ranges.
- The variation of 20 dB between high and low values in the sonograms between the yellow bands and the purple bands. This variation is audible under observed conditions.

The overall levels in one third octave band charts are provided to illustrate the difference between maximum and minimum sound levels in the measurement time period. These correspond to the peak and trough values and give a "first-cut" assessment of whether or not audible modulation, audible tonality, perceptible modulation, or perceptible tonality may exist. Charts are provided as examples of the sound character. The sonograms are taken from recorded audio files that are 60 or 30 seconds in length. Hence, the displayed sonogram charts can differ from the one third octave band charts, which are calculated over a full 10 minutes.

The case study illustrates the difficulties in measuring and assessing wind turbine sound. Sound level criteria referenced to an A-weighted sound descriptor do not accurately describe the sound or perception of a wind turbine or a wind farm.

The study by Thorne (2010) records that wind turbine sound at the residence is perceptible and can be analyzed and assessed in a meaningful way.

The sound character of the wind farm is clearly different from the locale and indicates the presence of modulating sound. The sonograms and third octave band charts presented are provided to illustrate the character of the sound. The method developed by H. Bakker, Astute Engineering, New Zealand (personal communication, 2010) displays sound character, modulation, tonality, or tonal complexes through sonograms. These show sound at various frequencies over time as shown in Plate 1. They can be thought of like a sheet of music or an old pianola roll; the left axis is frequency—musical pitch—while the bottom axis is time. Amplitude and frequency modulation can be identified in the sonograms by distinctive regular patterning at 1-second (or longer or shorter) intervals. Tonality and tonal complexes can also be identified using sonograms. The color indicates the loudness in unweighted dB (SPL) with the color bar at the right providing a key to the "loudness" in decibels associated with each color. The values (−30 to 20, for example) on the right-hand side of the sonogram are decibel levels. Loud notes appear yellow or while; soft notes would appear purple or black. (In these sonograms, much of the color scale has been made black so that peaks stand out better.) Generally, the sonograms are not calibrated against measured sound level but present a comparison between peak and trough (maximum and minimum) levels in a short period of time. At the time of recording it is possible to include reference sound levels in order to assess the sonogram values against measured values.

There are two types of sonograms shown, one is for audible frequencies (20-1,000 Hz) and the other is for low frequencies (0.8-20 Hz), referred to as *infrasound*. The use of sonograms can show the presence of modulation. The rumble/thump of

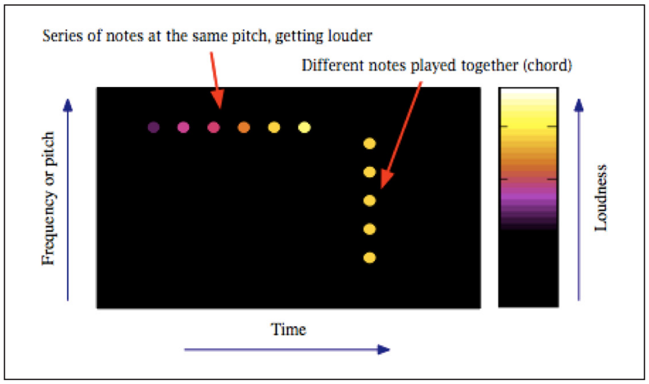

Plate 1. How to interpret a sonogram

wind turbine modulation has been demonstrated to exist in three geographically separate wind farms.

Sound Character at Residence, Plate 2

Plate 2 illustrates the sound of wind farm audible at 7:40 p.m. outside residence, as well as wind in trees, voices, setting-up activity, and a distant vehicle. The sonogram shows a distinctive 50 Hz tone from a nearby electrical source, as well as strong readings at 20 Hz, 16 Hz, and 6.3 Hz. These are indicator frequencies for potential adverse health response. The regular bands or modulations at around 1 Hz indicate wind turbine blade pass frequency. Higher frequency contents (800-5,000 Hz) not evident in the sonogram are evident in the third octave bands.

Sound Character at Residence, Plate 3

The audio file identifies wind and wind farm sounds. There are strong readings at 20 Hz, 16 Hz, and 6.3 Hz. These are indicator frequencies for potential adverse health response. The regular bands or modulations at around 1 Hz indicate wind turbine blade pass frequency. Higher frequency content (800-5,000 Hz) evident in the third octave band chart is not evident in the sonogram. Low-frequency content is evident in both the sonogram and the third octave band chart.

Sound Character at Residence, Plate 4

Wind farm not audible outside residence. The wind pattern is completely different from the previous two sonograms. There is a distinctive 90 Hz tone from an aircraft. Animal and bird noise provide the character. The strong readings at 20 Hz, 16 Hz, and 6.3 Hz have gone. The previous regular bands or modulations at around 1 Hz indicate wind turbine blade noise has gone and instead there are smooth bands of sound from “ordinary” wind flow.

Sound Character Between Two Sets of Turbines, Plate 5

The wind farm was audible at the measurement location as a distant rumble and some of the nearest visible turbines approximately 500 to 1,500 meters distant were moving slowly, as though they were starting up. The sound is similar to an aircraft overhead, although the sound was not from a plane. There are strong readings at 20 Hz and below on a regular basis although there was little or no breeze. The regular bands or modulations at around 1 Hz indicate wind turbine blade pass noise.

Sound Character Inside Residence, Plate 6

Sound levels measured inside a small bedroom. The audible sound character (200-400 Hz) is from distant voices within the house. Wind farm not audible outside residence: turbines to the north turning slowly, turbines to the south not turning. There are strong readings at 20 Hz and below on a regular basis. There was no ground-level breeze outside during the recording. There is evidence of normally nonperceptible infrasound and audible midrange frequencies within the bedroom.

Responses of Residents Living Near Wind Farms

Community noise exposure is commonly measured in terms of a noise exposure measure. Noise exposure is the varying pattern of sound levels at a location over a defined time period. The time period is most often 1 day (short term) or over weeks, months, or a year (long term).

The practical difficulty in locale measurements is that many of them are needed to describe a neighborhood. It is customary, therefore, to use a suitable single-number evaluation for community neighborhood noise exposure. Individuals, however, are different in their tolerance to specific sounds: there is a distinct duration-intensity relationship that varies depending on the character of the sound (Thorne, 2007).

There is no defined relationship that can predict when a noise is reasonable or unreasonable; for this to happen, the sound must be audible or perceptible to cause an adverse response in the person affected.

Previous wind farm investigations in New Zealand and Victoria, Australia, indicate that residences within 3,500 meters of a wind farm are potentially affected by audible noise and vibration from large turbines, such as those proposed. Residences within 1,000 to 2,000 meters are affected on a regular basis by audible noise disturbing sleep. Adverse health effects are reported and as these effects did not occur before the wind farms became operational a reasonable hypothesis is that the wind farm activity has a causal relationship (Thorne, 2007, 2011).

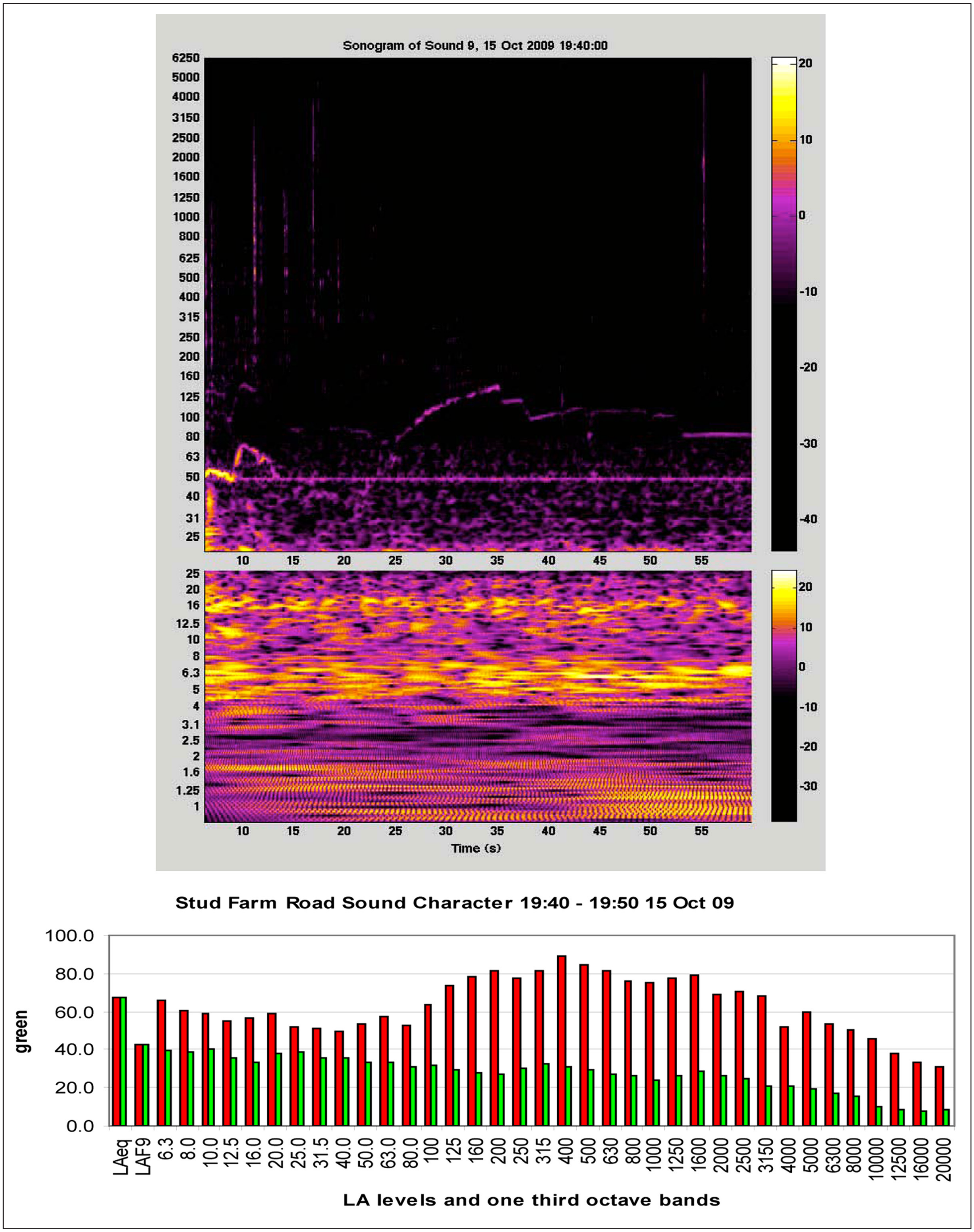

Plate 2. Sound of wind farm audible outside residence

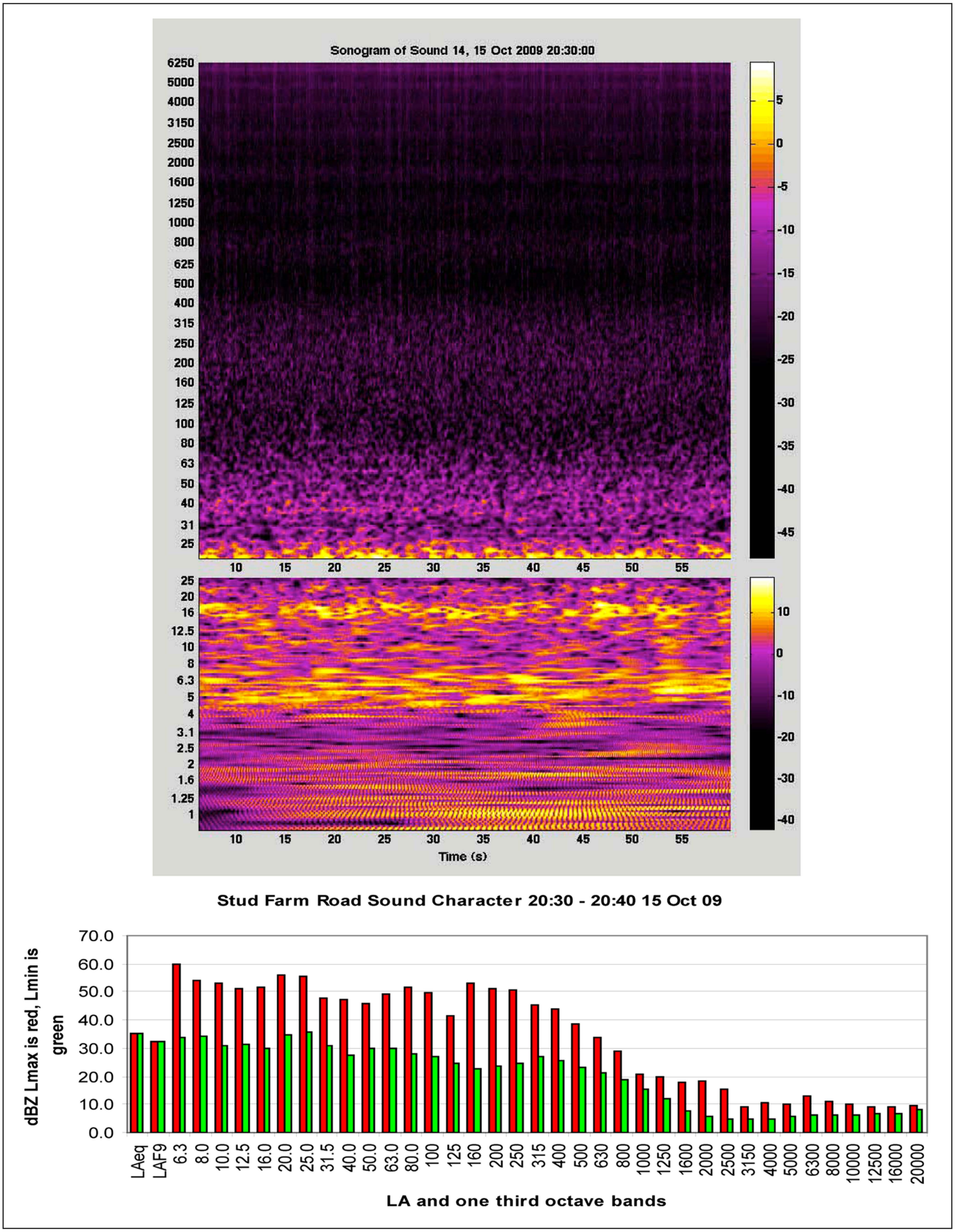

Plate 3. Sound of wind farm audible outside residence (low frequencies identified)

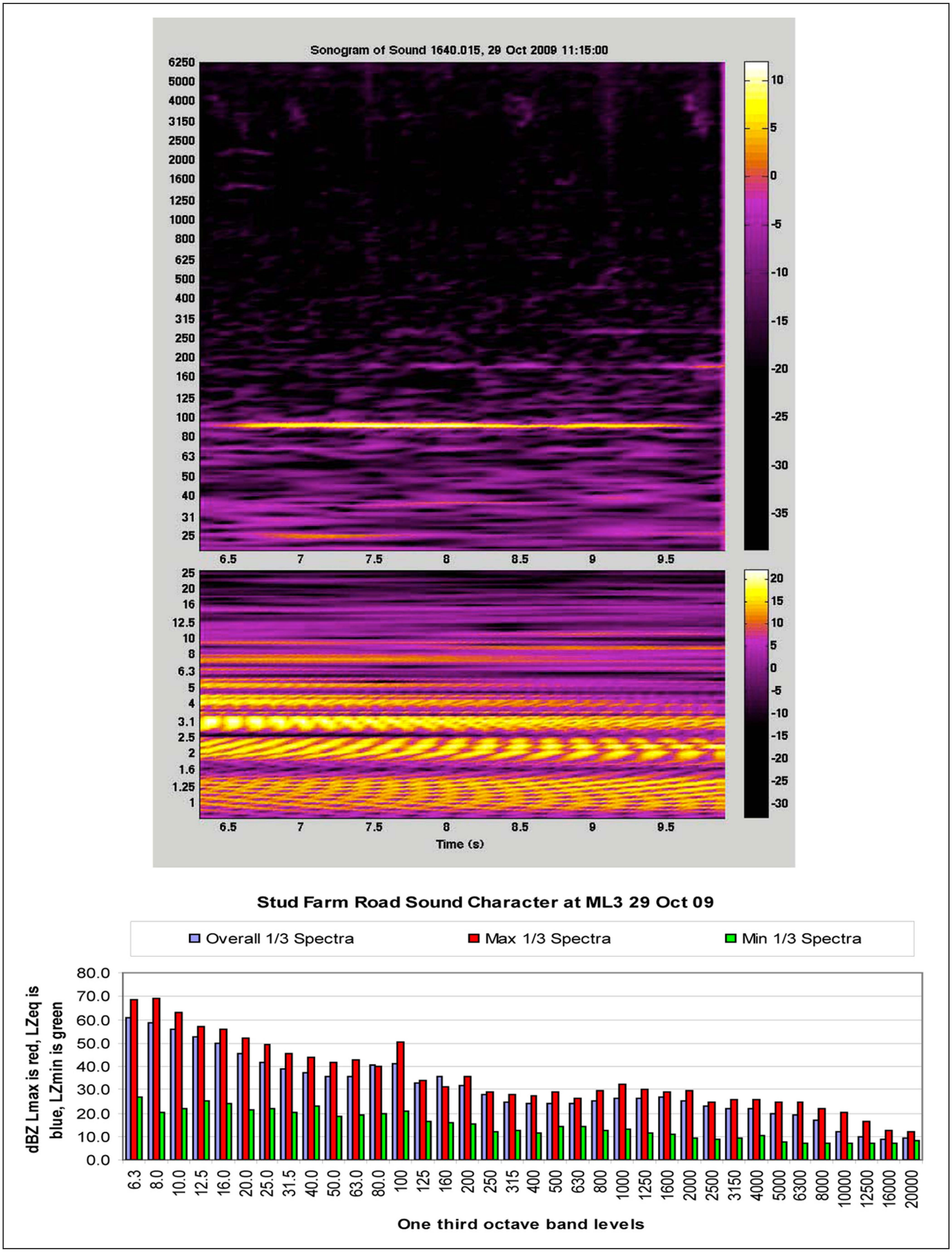

Plate 4. Sound of wind farm not audible outside residence

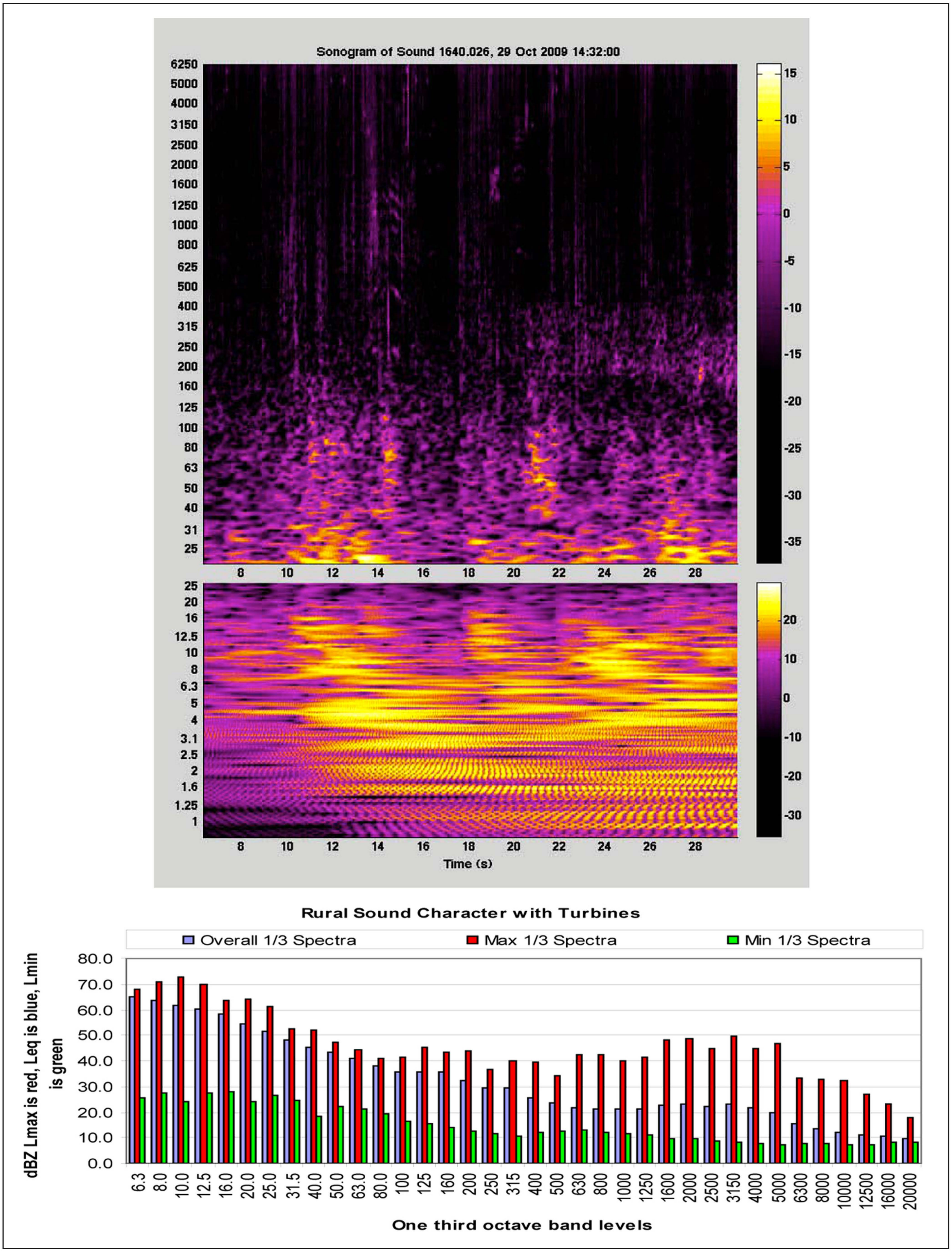

Plate 5. Sound character of wind farm turbines

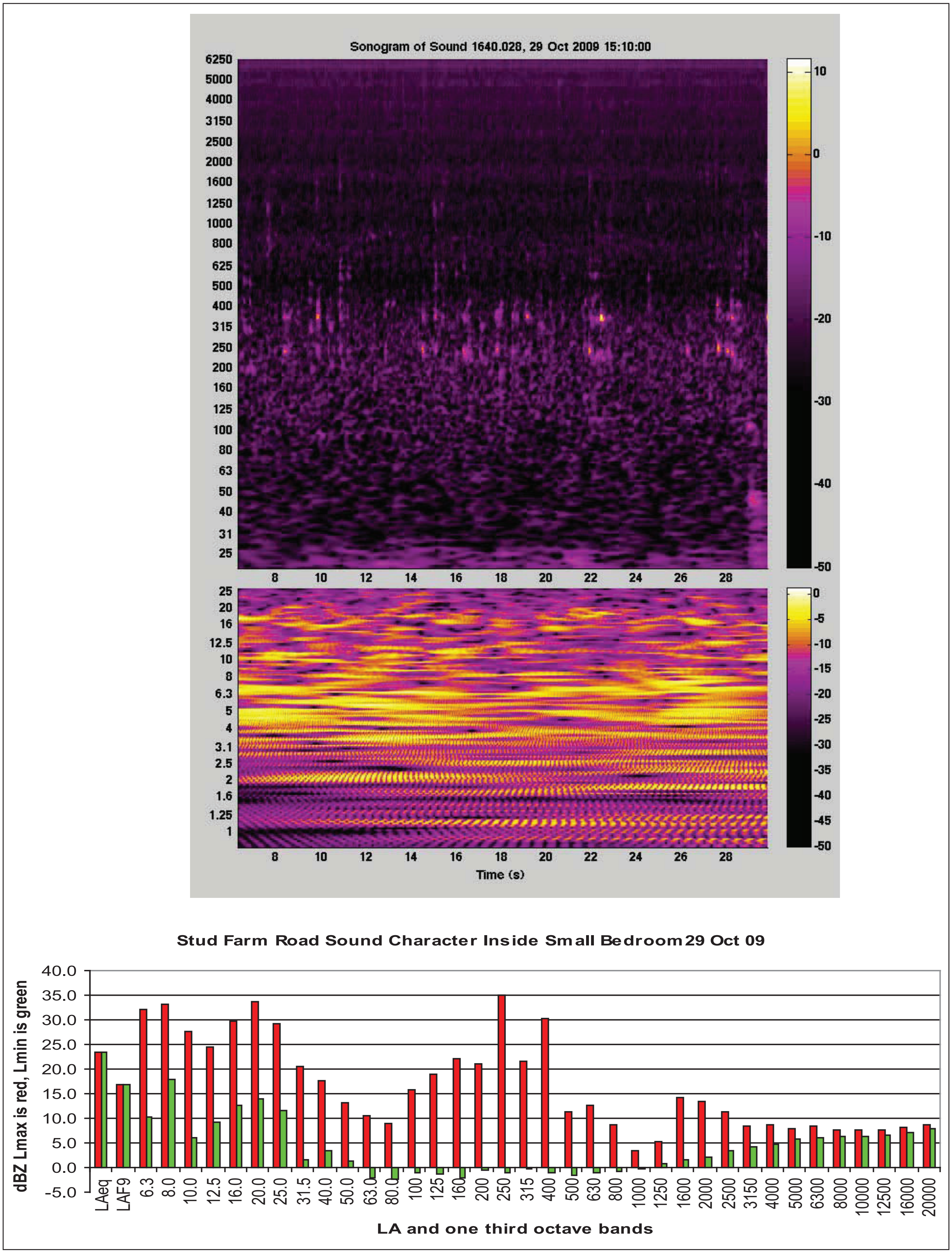

Plate 6. Sound character of wind farm inside a dwelling

The following three examples illustrate the effects of wind farms on residents living within the locale.

The Effects on People Living Near the Waubra Wind Farm, Victoria, Australia

The Waubra wind farm commenced operation in March 2009 in the Ballarat section and in May 2009 in the northern Waubra section. Within a short time nearby residents were becoming concerned about noise. By August 2009 adverse health effects were being reported. In September-October I interviewed five different families near the northern section of the wind farm, all of whom indicated some adverse reaction since the commissioning of a nearby wind farm earlier in the year. The families are all within approximately 1,000 to 2,000 meters of turbines and had at least two sets of turbines near to them. Under these circumstances, the residences are affected by wind farm activity over a range of wind directions. The interviews were preliminary in nature and standard psych and noise sensitivity tests were not conducted, nor were detailed health notes recorded.

Family A indicated headaches (scalp and around the head pressure), memory problems, and nausea when the turbines are operating. Symptoms include an inability to get to sleep and sleep disturbance, anxiety and stress, pressure at top and around head, memory problems, sore eyes and blurred vision, and chest pressure. When the turbines are stopped the symptoms do not occur. A difference in severity is recorded with different wind directions. A personal comment made states the following:

> I am having problems living and working indoors and outdoors on our property . . . problems include headaches, nausea, pain in and around the eyes, sleep disturbance, pain in back of head; we feel this is coming from generation of wind from wind farm as it is OK when turbines are stopped.

Family B indicated tinnitus, dizziness, and headaches since the turbines have started operating. The family also indicated sleep disturbance at night with the sound of the turbines interrupting sleep pattern, vibration in chest at times, and tiredness and trouble concentrating during the day. The family did not have problems sleeping when not at Waubra overnight.

Family C indicated that the noise coming from the turbines at night disturbed sleep. During the day there was noise that causes bad headaches, sore eyes causing impaired vision, earache, and irritability.

Family D indicated suffering from sleep disturbance, headaches, nausea, and tachychardia (rapid heart rate) since the turbines started operating.

Family E indicated that when the turbines were operating symptoms included feeling unwell, dull pains in the head (acute to almost migraine), nausea, and feeling of motion sickness. Symptoms at night when the turbines were in motion included sleep disturbance from noise and vibration (unable to get any meaningful deep sleep) and sleep deprivation leading to coping problems. The problems were reported as follows:

> Some days when the wind is in the north-east my eyes feel swollen and are being pushed out of the sockets. I have a buzzing in my ears. On these days I feel it very difficult to summon memory and difficult to concentrate.
>
> The sound of the turbines when functioning is on most days so intrusive that it affects my concentration and thought processes when performing complex tasks. I suffer from sleep interruption as a direct result of the noise, which then affects my ability to function at 100% the following day. One is aware of a throbbing in the head and palpitations that are in synchrony with the beat of the turbines and to a degree the flashing of the red lights. Because of this impact on my everyday life it causes me great stress and in turn great irritability.

Two families identified blade glint/flicker and the red warning lights on the top of each tower as an additional source of annoyance.

Statutory declarations (June 2010) concerning noise issues have been declared by residents affected by the Waubra wind farm. Noise from the turbines is being experienced by residents within approximately 1,000 meters of the nearest turbines and at distances of approximately 3,000 to 4,000 meters distant from the nearest turbines. The locales where the residents experience noise are shown in Plate W1. The noise and health effects experienced by residents are presented in Table W1.

The Waubra north and Ballarat locales are rural in nature with relatively low hills and rolling countryside. The northern section of the wind farm is illustrated in Plate W2. The locale is affected by southwest winds at turbine level but can be relatively calm at residences. The prevailing winds at Ballarat airport are shown in Figure W1. The measured wind directions are given to illustrate the importance of accurate wind data in predicting or assessing complaints.

The Effects on People Living Near the "West Wind" Wind Farm, New Zealand

The "West Wind" wind farm commenced operation in May 2009. From my observations at Makara, New Zealand, at a residence situated approximately 1,200 to 1,300 meters from 5 turbines and within 3,500 meters of 14 turbines there is known probability that the wind farm will exhibit adverse "special audible characteristics" on a regular basis resulting in sleep disturbance, annoyance, and stress.

The observations and measurements being recorded at Makara involve the residents taking notes of the noise heard when they are awakened. At the same time, a fully automated monitoring system records exterior audio as well as exterior and interior sound level data in summary levels and third octave band levels. This allows the generation of tracking

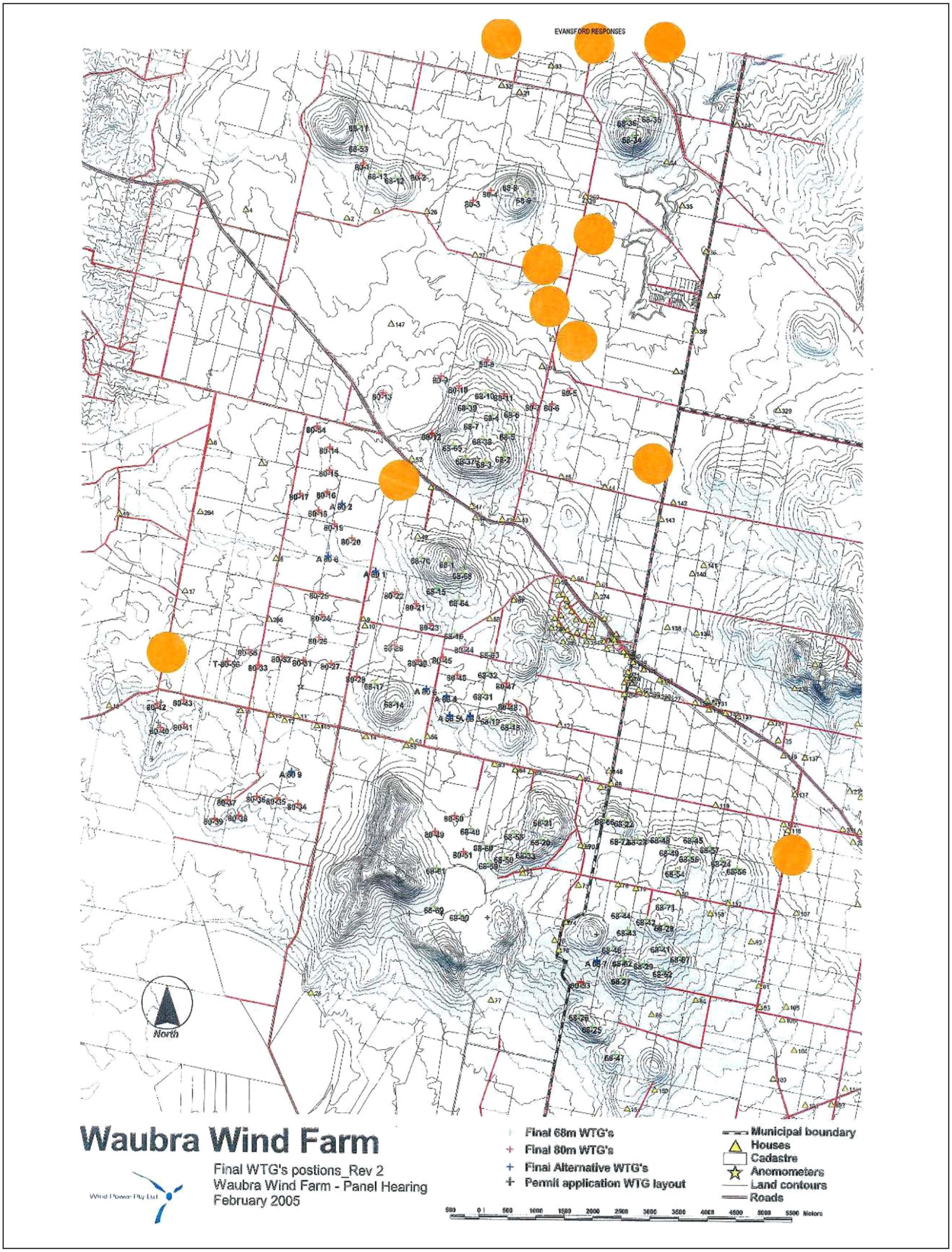

Plate W1. Locales in Waubra affected by Waubra wind farm turbine noise
Note. The locales affected by wind farm noise are identified by the orange circles.

Table W1. Waubra Wind Farm Perception and Complaint Analysis

Locale	Distance	Effects of Noise
1	1,500-2,500	Sleep disturbance, headaches, affects eyes and back of head, tinnitus. Worst affect is while working the farm. Heart pressure changes.
2	1,000	Sleep disturbance, headaches, high blood pressure.
3	1,000-1,300	Sore eyes and headaches when the turbines are operating.
4	1,250-3,000	Sleep disturbance. Affects people working on the farm. Headaches, earaches, blood pressure changes, and poor eye sight.
5	1,300-2,200	Insomnia, headaches, sore eyes, dizziness, tinnitus, and heart palpitations. Deteriorating health due to lack of sleep and stress levels. Unable to sleep through the night. Affects while working outside on the farm.
6	2,000-2,300	Headaches and pressure in ears when working on the farm.
7	550-1,400	Sleep disturbance, windows vibrate. Affects while working on the farm. Headaches, lack of sleep, major problem with flicker. Excessive noise under a strong southwest wind.
8	1,000-3,500	Headaches when working farm within 1500 meters of turbines. Dizziness when two turbines inline and in sync, effect went when approximately 300 meters out of alignment. Sleep awakenings and disturbed by pulsating swish. Heart palpitations, vibrating sensation in chest and body. Headaches while at home. Stress and depression.
9	3,500-4,300	Frequently suffer from headaches, tinnitus, irritability, sleepless nights, lack of concentration, heart palpitations. Turbines exhibit a loud droning noise and pulsating whoosh.
10	3,400-3,800	Headaches, ringing in ears when turbines are operating. Pressure in ears, heart palpitations, and anxiety attacks. Awaken at night, sleep disturbance.
11	3,000-4,600	Elevated blood pressure, heart palpitations, ear pressure and earache, disrupted sleep, increasing frequent headaches, head pressure, vibration in body, mood swings, problems with concentration and memory. Awaken at night, sleep disturbance.
12	1,000-1,200	Headaches, sickness, frequent sleep disturbance, very stressed. Affects personal life. Lights on turbines cause extreme distress. Ear pressure and loss of balance while working on the farm. Enormous pressure and stress on home and work.

Note. "Distance" is the distance in meters between the locale and the nearest turbines. The distances vary where turbines are in different directions surrounding the locale. Each locale contains one or more affected families. A common observation is that the adverse health effects noted did not exist before the wind farm commenced operation or diminish/disappear when not in the district affected by turbines.

data and sonograms for compliance and unreasonable noise assessment. The complaint data are retained by the City Council. Statistical data are retained by the wind farm operator and summarized for the Council. Audio data for real-time analysis of special audible characteristics are not recorded by either the Council or the wind farm operator. Audio data are recorded, however, by one affected resident.

In the period April 2009 to March 31, 2010, a total of 906 complaints were made to the Wellington City Council, New Zealand, concerning noise from the wind farm at Makara. These complaints were made by residents living near to and affected by the wind farm. An analysis of the complaint history was made by acoustical consultants working for the wind farm company. From 64 households in a population of approximately 140 occupied residences, 57% of the complaints were from 10 households and 79% were from 20 households.

The character of the 650 complaints was sorted by an independent researcher. Rumble, with 252 mentions, was the most common characteristic. Hum and thump are the next most common annoying sounds. In comparing complaints of noise outside to inside, of 650 complaints, only 23 specifically mentioned the noise as being outside.

In personal interviews at Makara, some residents identified nausea as a problem. In the most severely affected cases known, the residents have bought property and moved away from their farm.

Low-frequency sound and infrasound are normal characteristics of a wind farm as they are the normal characteristics of wind, as such. The difference is that "normal" wind is laminar or smooth in effect whereas wind farm sound is non-laminar and presents a pulsing nature. This effect is evident even inside a dwelling and the characteristics are modified due to the construction of the building and room dimensions. Of the indoor complaints, 4.5% specifically mentioned sleep disturbance.

The Makara complaints were limited to a small locale. Complaints were from the whole of the district, that is, a distance of approximately 12 km. The turbines are situated in both clusters and rows. The locale "Makara" is a small village and school affected by a cluster of approximately 14 turbines within 2,000 meters; the locale "South Makara" is a line of residences facing a line of 25 turbines within 2,000 meters over approximately 5 km. The issue is that turbine noise is known, it can be defined by character and distance, and it does have significant impact on a large number of people.

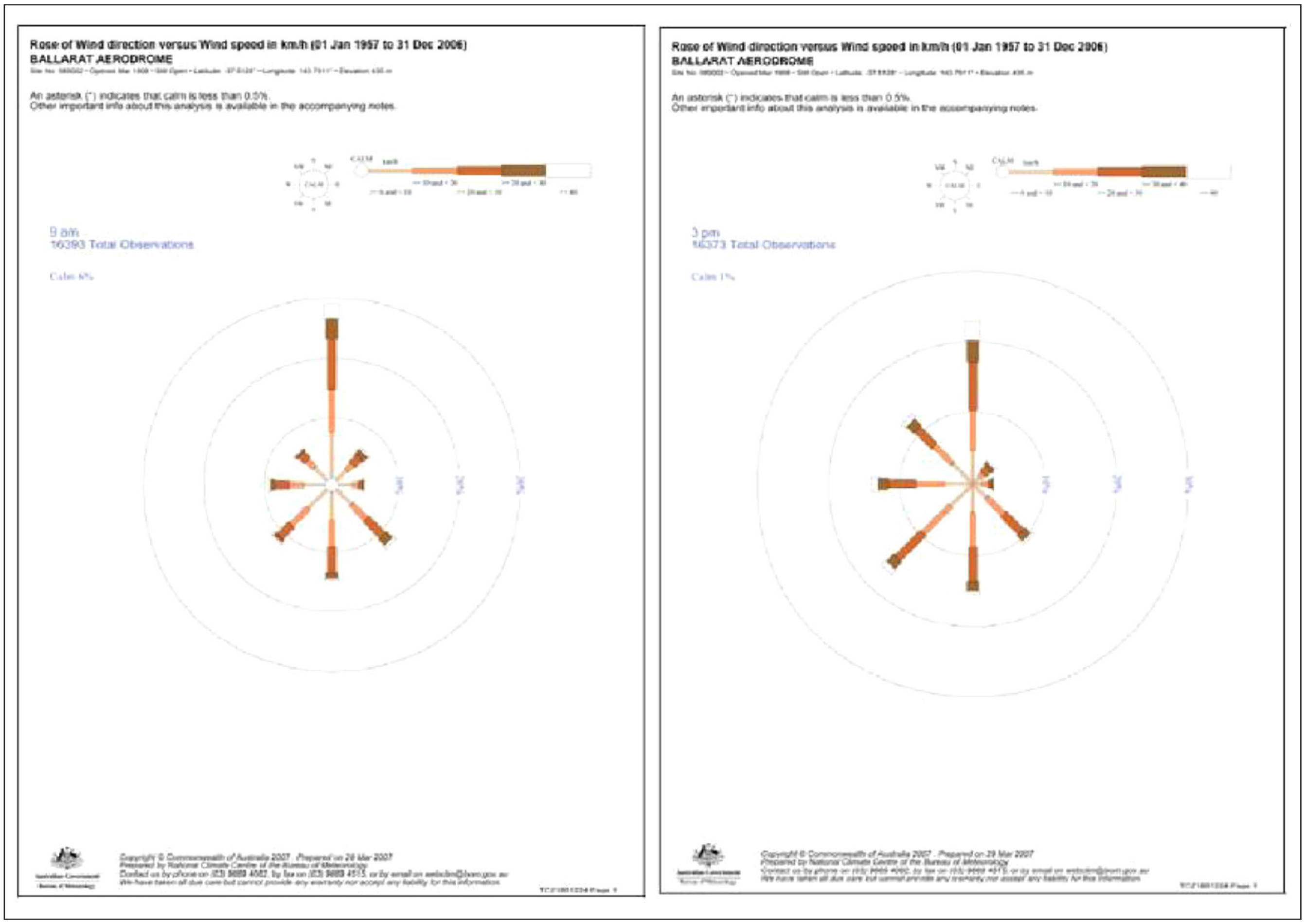

Figure W1. Wind rose, Ballarat Aerodrome, mid-morning and mid-afternoon

The turbines are Siemens 2.3 MW machines situated approximately 1,200 to 2,200 meters from residences.

Nausea and sleep disturbance were reported by one visitor to a residence 2,200 meters from the nearest turbine. The residents also complained about the visual nuisance caused by blade glint and flicker, as well as the red glow from the warning lights on top of each tower. A complaint (March 2010) about the operation of the wind farm expressed the following:

> We have had a persistent level of disturbance noise now for several hours throughout the evening that is now preventing us sleeping since 11:15 p.m. The predominant noise is a continuous loud booming rumble that is even more noticeable after a gust at ground level. When the wind noise drops, the background noise from the turbine continues and is also felt as a vibration being transmitted through the ground. Even with wind noise the vibrations in the house continue. The varying wind speed also causes a beating noise from the blades that occurs in cycles creating yet another form of noise disturbance.

A second resident said the following:

> We are 2 km away to the east and the thumping also penetrates our double glazing. The reverberation is somehow worse inside the house.

And a third resident said the following:

> We . . . get the low-frequency thump/whump inside the house, is very similar to a truck driving past or boy racers sub woofer 100 meters away . . . we have no line of sight turbines and the closest one in 1.35 km away. There are however 27 turbines within 2.5 km (which would apply for the whole village). The sound is extremely "penetrating" and while we have a new house with insulation and double glazing, the low-frequency modulation is still very evident in the dead of night. It is actually less obvious outside as the ambient noise screens out the sound.

The valley is affected by strong winds at turbine level but can be relatively calm at residences. The prevailing wind at

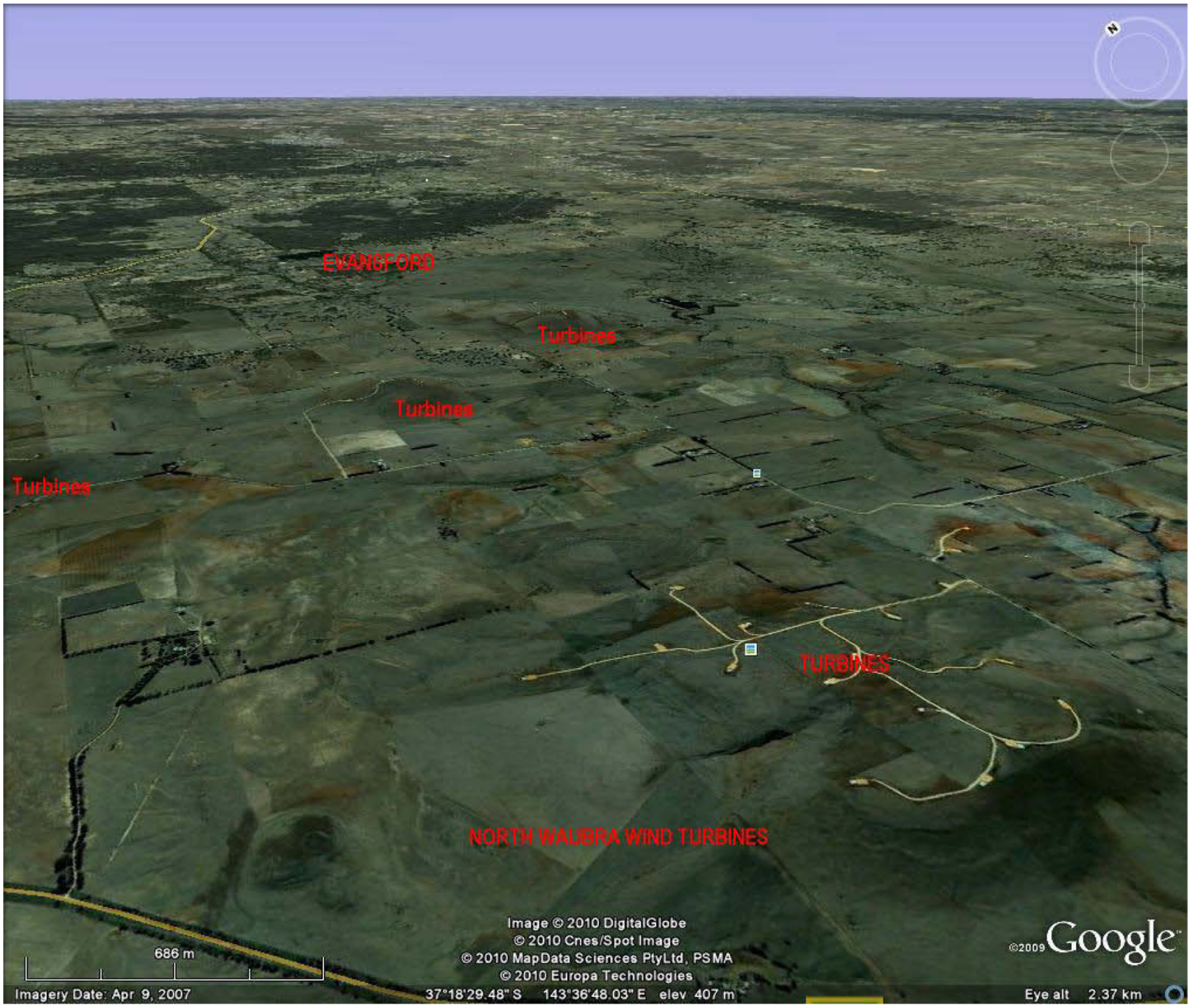

Plate W2. North Waubra locale, residents and the Waubra wind farm

the turbines' mast at 40 meters above ground is shown in Figure WW1. The measured wind directions are given to illustrate the importance of accurate wind data in predicting or assessing complaints.

The Effects on People Living Near the "Te Rere Hau" Wind Farm, New Zealand. In the period from May 2009 to March 31, 2010, a total of 378 complaints about noise were made to Palmerston North City Council, New Zealand, concerning the Te Rere Hau wind farm. The complaints were made by persons within approximately 2,300 meters south, 3,100 meters southwest, and 2,100 meters to the north of the center of the "97"-turbine wind farm. Complaints concerned both the loudness and character (grinding, swishing) of the sound from the turbines, a two-blade 500 kW design.

The Te Rere Hau wind farm complaints are important as they reflect the concerns of a rural community with relatively few people living within 3,500 meters of the center of the wind farm. Te Rere Hau is a densely packed design with wind turbines arranged in a grid pattern. In the 10 months for which records have been seen, 21 different residents complained about noise, with 2 residents logging more than 40 complaints each and a further 8 logging more than 10 complaints each. This indicates issues with wind farm placement and design that can be mitigated by careful consideration of turbine choice, turbine siting design, and

Table WW1. West Wind Perception and Complaint Analysis Till November 2009

Locale	Distance	Effects of Noise
1	1,200-1,300	Kept awake with turbine noise pulsing in bedroom. Sleep disturbance. Sounds not masked by wind in trees or stream.
2	1,200-1,300	Possible to hear and feel the turbines (20 of them) over usual household noises during the day and evenings. At night disturbs sleep patterns and affects health and well-being. Can hear the noise through the bed pillow. Sounds like a tumble dryer.
2	1,200-1,300	Can hear the turbines inside and outside the house during the day and at night. Disturbs sleep and affects health (tiredness). Family is stressed.
3	1,700	Sound is a rhythmic humming heard inside and outside the house during the day and at night. Northwest wind brings noise, southerly does not. Noise is highest when it is calm at the house but windy at the turbines. Turbines audible inside the home with TV on. Noise is a low hum.
4	1,750	When the wind is from the north to northwest the noise penetrates into the home. Persistent deep rumbling around 1-second interval and lasts for 10 to 20 seconds and then abates. Awakens and disturbs sleep. Generates annoyance and irritability.
4	1,700	Disturbs sleep. Turbines are heard when it is calm at the house and windy at the turbines. Annoyance, nausea, earaches, and stress.
5	2,100	Turbines audible in bedroom. Awaken and disturbs sleep. Creates pressure in head and headache. Feeling tired and distressed.
6	2,000	Northwest wind brings noise and disturbs sleep.
7	1,250	Northwest sound is constant thumping, pulsing. Cannot stand being in the house or around the property, sick feeling, headaches, tight chest. Can be heard at night cannot sleep, get agitated, and wound-up. Has ruined peace and tranquility.
7	1,250	Northwest wind, mild to wild, sound is constant thrumming. Noise is intensified in the house and more noticeable at night. Feeling of nausea precludes sleep. Disturbed and sleepless nights.
8	1,500-2,000	Turbine noise heard within the home. Severe sleep deprivation from interrupted sleep and lack of sleep. Fear of causing an accident on the farm due to lack of sleep. Noise at night is a southerly with a grinding rumbling sound. Noise from the northwest grinding a "plane takeoff" noise. Lot of ringing in ears. Easily heard above the background noise. Depression due to noise at night and lack of sleep.
9	750	Noise from the southerly winds rumbling, grinding all day and night. Trouble sleeping.
10	2,200	Regular sleep disturbance, sound like a plane. Louder inside the home than outside. Northwest wind thumping or rumbling sound, noise and vibration in the home (double glazed). Headaches. Low-frequency humming. Awakenings and sleep deprivation.

Note. "Distance" is the distance in meters between the locale and the nearest turbines. Each locale contains one or more affected families.

consideration of neighbors and long-term meteorological conditions. Plate TRH1 presents the impact of the wind farm on nearby residences. The number of complaints lodged by the residents is indicated in the plate. Table TRH1, for a single residence, illustrates the common thread of the noise problems found and the relationship to weather conditions. The residence is approximately 1,200 meters from the nearest row of wind turbines. The position of the wind farm on a plateau above the residences is illustrated in Plate TRH2. The measured wind directions are given in Plate TRH3 and illustrate the importance of accurate wind data in predicting or assessing complaints. The complaint numbers are very high for wind farms that supposedly are complying with their approval conditions. While the background levels may be achieved and this has yet to be proven, the wind farms are a significant source of unreasonable noise. The number and history of the complaints emphasizes the importance of buffer zones and wind farm design so noise can be mitigated by careful consideration of turbine choice, turbine placement, consideration of neighbors, and long-term meteorological conditions.

Real-World Noise Compliance Problem at a Wind Farm

The Te Rere Hau wind farm in New Zealand is presently the subject of a legal review of its compliance and the methodologies applied to measure background sound levels and compliance levels (*PNCC v. NZ Windfarms*, 2010). In brief, it is understood that specific issues raised are the following:

- The Te Rere Hau wind farm is being operated at levels higher than those predicted in the (wind farm) application
- The respondent has substantially underestimated the effects of the wind farm noise on the amenity of the area
- The AEE concluded noise from the wind farm would not exhibit special audible characteristics (i.e., clearly audible tones, impulses, or modulation of sound levels). This conclusion is inaccurate [reasons given]

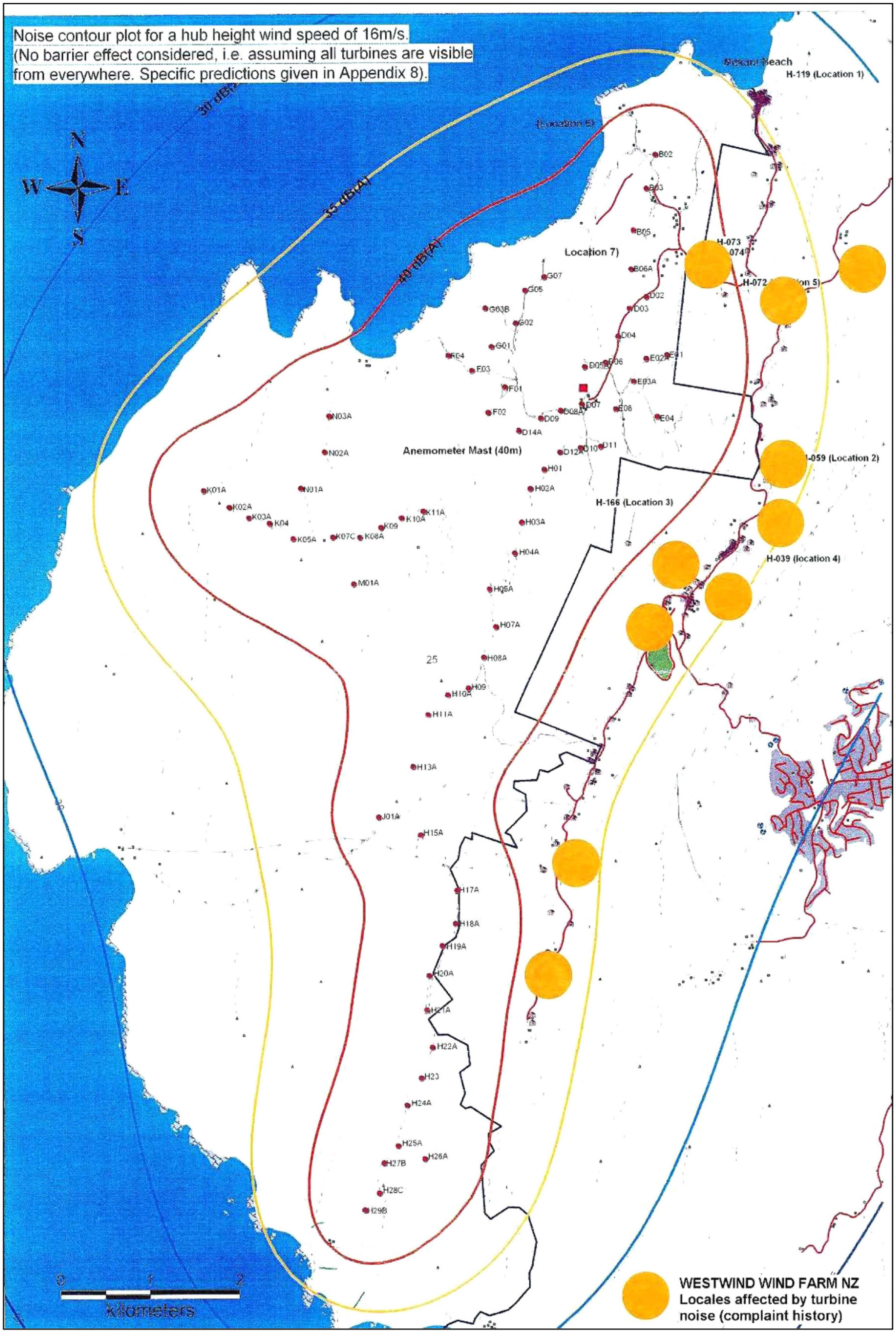

Plate WW1. Locales in Makara affected by "West Wind" wind farm turbine noise

Plate WW2. Makara Valley residents and the "West Wind" wind farm
Note. The turbines (marked in red) are situated on the top of the range and the residents are in the valley (Makara Village and blue squares)

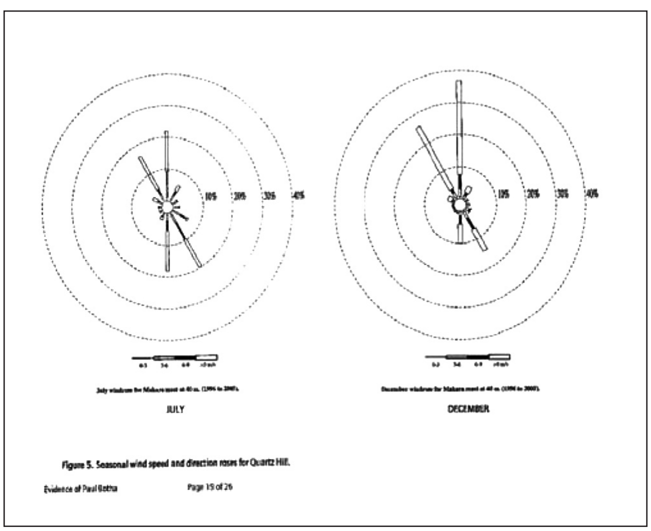

Plate WW1. Prevailing winds for Makara at the wind farm mast (40 meters)

- The actual experience of residents (located up to 2.18 km from the nearest turbines) and the number of complaints made to the Council indicating there are noise effects (which also exhibit special audible characteristics) being experienced at a significant number of local properties
- The actual results reported in the revised compliance report (April 2010) demonstrate the actual sound levels from the wind farm are significantly higher (up to 12.8 dBA higher) at the monitoring location under certain wind speeds and directions than predicted
- While monitored noise included noise from all sounds in the area (not just wind farm noise), the uncertainty as to the actual wind farm noise levels warrants further investigation. A new noise testing specification is the subject of the memorandum of December 21, 2010.

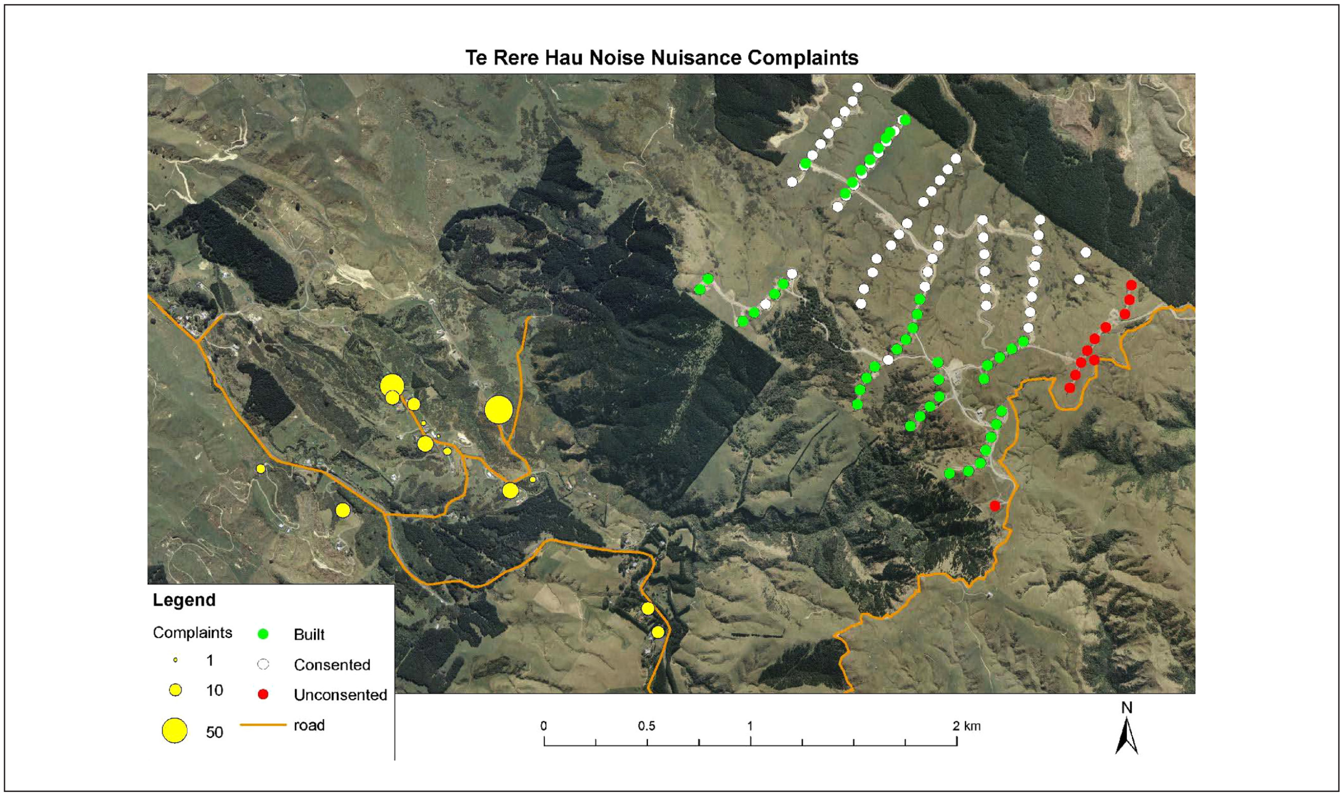

Plate TRH1. Te Rere Hau wind farm complaints by location

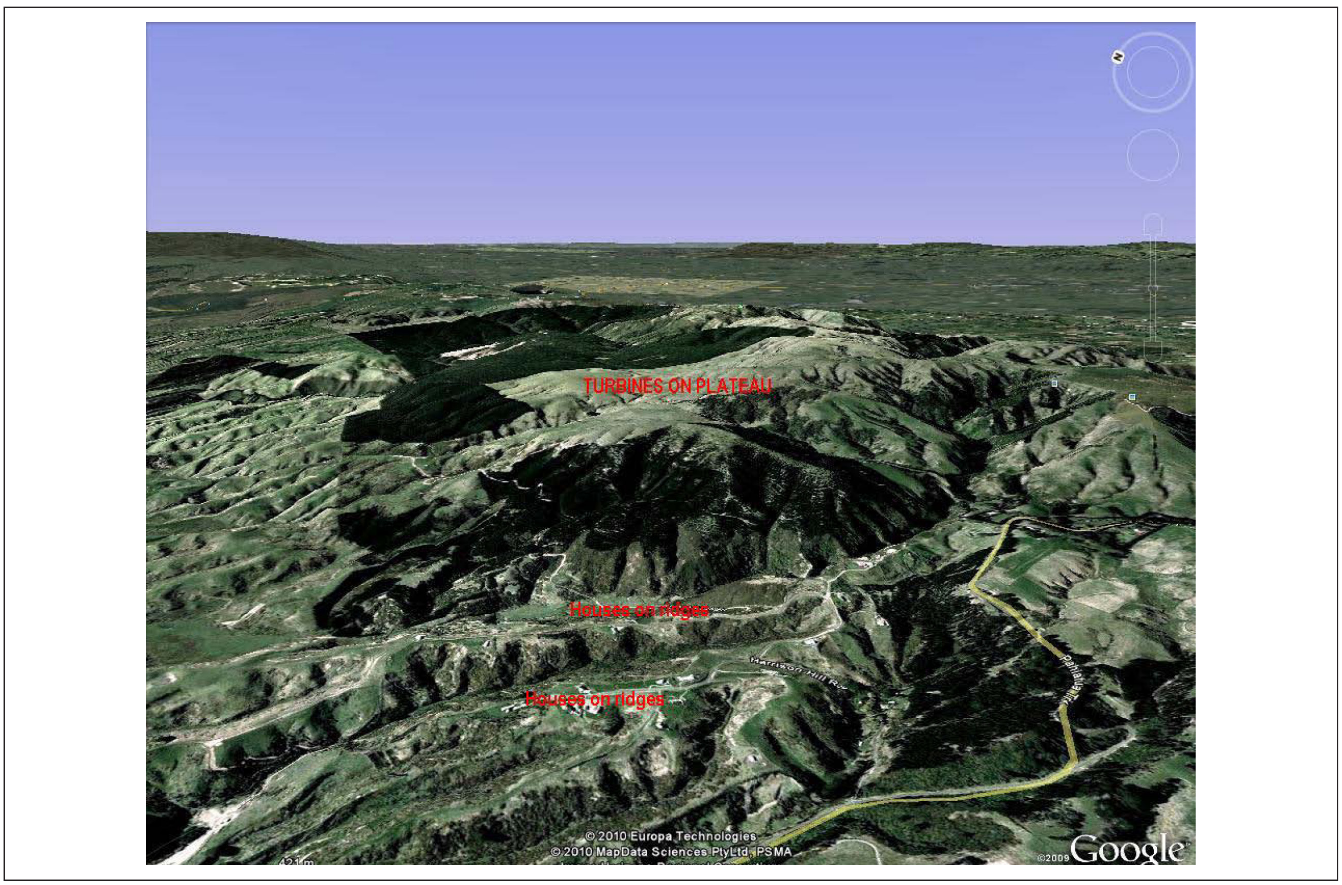

Plate TRH2. Te Rere Hau wind farm in relation to residences

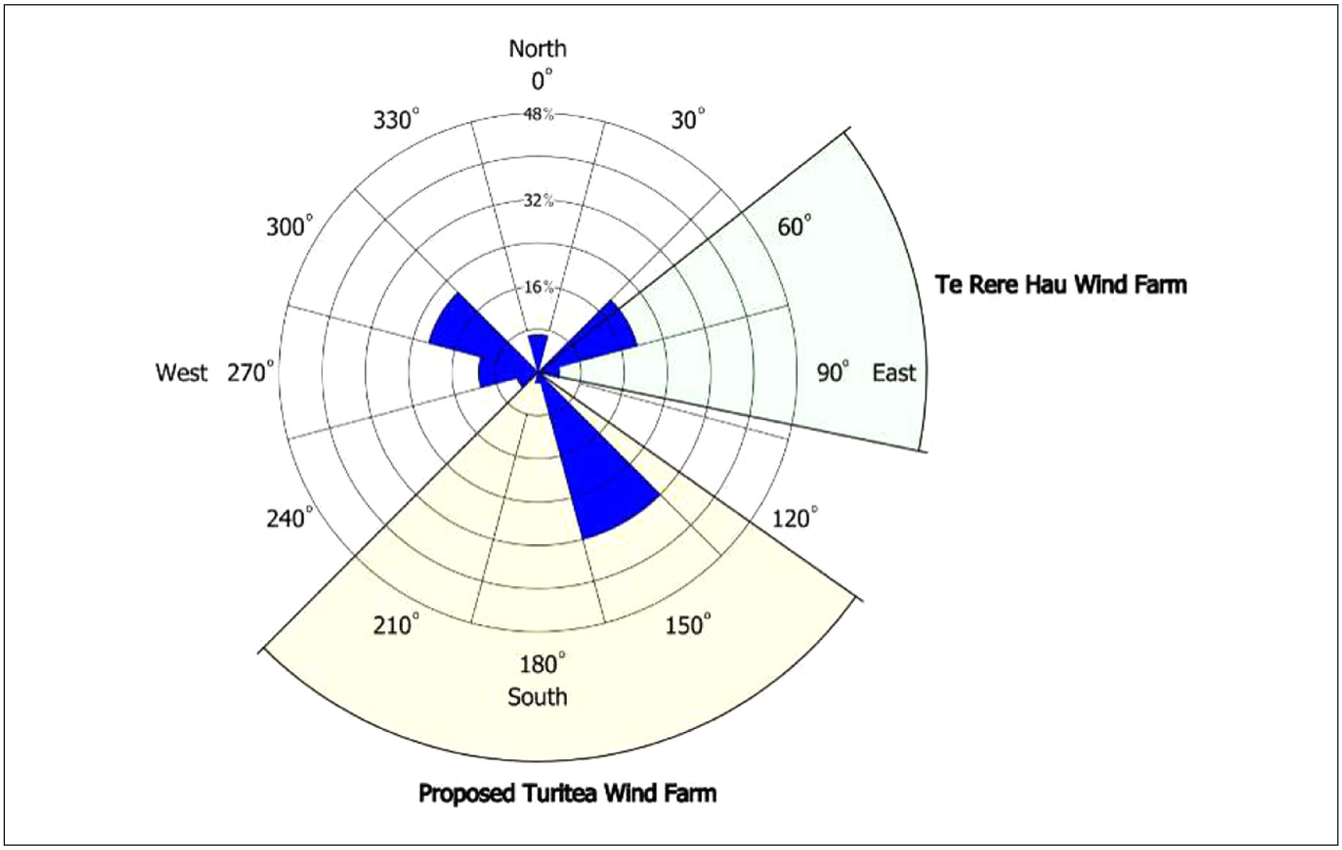

Figure TRH1. Wind Rose for May to September 2009 illustrating existing wind farm (Te Rere Hau) and effect from a proposed wind farm (Turitea) to the south

Conclusions

Personal perception of a sound is investigated through assessment of personal noise sensitivity, personal perception of the characteristics of the sound, and observable adverse health effects. Noise includes vibration in any form that can be "felt" by a person. There is, despite the differences in opinion as to cause, considerable agreement between the parties—residents, clinicians, and acousticians—as to observable health effects from unwanted sound. There are clear and definable markers for adverse health effects before and after the establishment of a wind farm and clear and agreed health effects due to stress after a wind farm has started operation. It is the mechanism of the physical or mental process from one to the other that is not yet defined or agreed between affected persons, clinicians, and psychoacousticians.

- It is concluded that, for the reasons given in this article, compliance criteria of a single value, such as 35 dB(A) measured as the equivalent level, LAeq; 40 dB(A) measured as the background level, LA95; or the "background plus 5dB" sound level, whichever is the greater are not acceptable. This is due to the general failure of approval conditions to provide clear and specific methodologies to measure wind farm sound under compliance testing conditions or under complaint conditions when turbine sound is part of the ambient sound.
- It is concluded that wind farms exhibit special audible characteristics that can be described as modulating sound, impulsiveness, or as a tonal complex. Compliance monitoring must include real-time measurement of special audible characteristics and infrasound.
- It is concluded that frequent short-term variations in air pressure (infrasound) may lead to adverse health effects in individuals.
- It is concluded that meteorological conditions, wind turbine spacing, and associated wake and turbulence effects, vortex effects, wind shear, turbine synchronicity, tower height, blade length, and power settings all contribute to sound levels heard or perceived at residences. Current noise prediction models are simplistic, have a high degree of uncertainty, and do not make allowance for these significant variables.
- It is concluded that noise numbers and sound character analyses are meaningless if they are not firmly linked to human perception and risk of adverse effects.

Table TRH1. Te Rere Hau Noise Complaints, August 2009 to February 2010, Single Residence

Date and Time	Wind Direction	Complaint
07/08/09, 5.45 p.m.		Noise from wind farm
20/08/09 6.55 a.m.	South-southeast	Wind farm loud this morning
20/08/09, 8.45 a.m.	South-southeast	Loud wind mills at 5.00a.m.
21/08/09, 6.32 a.m.	East	Wind farm noise
22/08/09, 12.51 p.m.	East	Medium strength, swooshing, and grinding, only ½ on
29/08/09, 8.45 a.m.	West	Very loud again today
15/09/09, 6.31 p.m.	East	Loud noise coming from wind farm
11/05/09, 10.48 a.m.	West	Light wind, wind farm extremely loud
21/11/09, 5.42 a.m.	West	WF too loud
05/08/09, 7.02 a.m.		Noise from Te Rere Hau this morning
09/08/09, 6.02 p.m.		Excessive noise Te Rere Hau
11/08/09, 1.03 p.m.		Windmills beeping noise every 2 minutes
04/09/09, 8.05 a.m.	East	Continuous noise last half hour
09/09/09, 11.24 a.m.	West	Started turbines 103 and 104, now noisy
11/09/09, 6.21 a.m.	North	Light northerly, noise since he got up
19/09/09, 10.49 a.m.	South	Very noisy again today
20/09/09, 8.13 a.m.	East	Loud noise
28/09/09, 7.15 a.m.	Northeast	Wind farm noise
07/10/09, 5.32 p.m.	West	Light wind, loud noise from wind farm
08/10/09, 7.42 a.m.	West	Light wind, swooshing noise this morning
09/10/09, 7.02 a.m.	Northeast	Light wind, wind farm really loud this morning
10/10/09, 9.59 a.m.	South	Light wind, would like to complain about noise
12/10/09, 7.48 a.m.	North	Light wind loud noise from wind farm
20/10/09, 3.53 p.m.	South	Loud noise at wind farm
08/11/09, 9.36 a.m.		Still, noise today
16/11/09, 7.25 a.m.	West	Lots of noise coming from wind farm this morning
17/11/09, 6.27 p.m.	West	Light wind, very loud tonight
20/11/09, 7.22 a.m.	West	Noise complaint
22/11/09, 7.16 p.m.	East	Light wind, wind farm very noisy
04/12/09, 6.18 a.m.	West	Noisy this morning
07/12/09 6.21 p.m.	West	Loud wind farm
09/12/09, 6.50 a.m.	West	Light wind, droning noise
15/12/09, 7.28 a.m.	South	Noisy wind turbines
19/12/09, 7.04 p.m.	West	Light wind noise from turbines over days whirring
25/12/09 8.59 a.m.	West	Light westerly, very loud today
16/01/10, 9.09 a.m.		Noise
17/01/10, 7.44 a.m.	South	Light-medium southerly wind farm quite loud today
17/01/10, 6.58 p.m.	South	Southerly wind, wind mill noise
18/01/10, 7.26 a.m.	Southeast	Medium wind, wind turbine noise last hour
18/01/10, 6.45 p.m.	East	Noise very bad
18/01/10, 10.54 p.m.	Southeast	Extremely loud
19/01/10, 7.28 p.m.	West	Turbines causing a lot of noise tonight
21/01/10, 8.21 p.m.	East	Loud noise from the turbines
25/01/10, 4.43 p.m.	East	Wind mill noise
26/01/10 8.12 a.m.	East	Medium wind, wind turbines making a lot of noise
28/01/10, 7.27 p.m.	East	Light wind, turbines are noisy again this evening
29/01/10, 10.21 a.m.	East	Loud noise from blades and mechanical noise
29/01/10, 6.12 p.m.	East	Med wind same noise as usual coming from turbines
02/02/10, 6.51 p.m.	East	Loud noise from wind farm
03/02/10, 7.19 p.m.	East	Noise from wind farm
04/02/10 7.01 a.m.	East	Noise loud this morning
05/02/10, 6.22 a.m.	East	Light, loud today
05/02/10, 5.57 p.m.	East	Light wind, same whirring gearbox noise as usual
07/02/10, 12.49 p.m.	Northwest	Excessive noise
08/02/10, 6.58 a.m.		Wind farm very loud this morning
08/02/10, 8.16 p.m.	East	Light wind
10/02/10, 7.11 a.m.	North	Te Rere Hau noisy this morning
15/02/10, 8.14 p.m.	East	Medium wind
16/02/10, 7.50 a.m.	East	Turbine noise in east direction at least hour

- It is concluded that no large-scale wind turbine should be installed within 2,000 meters of any dwelling or noise-sensitive place unless with the approval of the landowner.
- It is concluded that no large-scale wind turbine should be operated within 3,500 meters of any dwelling or noise-sensitive place unless the operator of the proposed wind farm energy facility, at its own expense, mitigates any noise within the dwelling or noise-sensitive place identified as being from that proposed wind farm energy facility to a level determined subject to the final approval of the occupier of that dwelling or noise-sensitive place.

In my opinion, based on my training, experience, measurements, and observations, serious harm to health occurs when a susceptible individual is so beset by the noise in question that he or she suffers recurring sleep disturbance, anxiety, and stress. The markers for this are (a) a sound level of LAeq 32dB outside the residence and (b) above the individual's threshold of hearing inside the home.

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Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis

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Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis

Robert Y. McMurtry[1]

Abstract

Internationally, there are reports of adverse health effects (AHE) in the environs of industrial wind turbines (IWT). There was multidisciplinary confirmation of the key characteristics of the AHE at the first international symposium on AHE/IWT. The symptoms being reported are consistent internationally and are characterized by crossover findings or a predictable appearance of signs and symptoms present with exposure to IWT sound energy and amelioration when the exposure ceases. There is also a revealed preference of victims to seek restoration away from their homes. This article identifies the need to create a case definition to establish a clinical diagnosis. A case definition is proposed that identifies the sine qua non diagnostic criteria for a diagnosis of adverse health effects in the environs of industrial wind turbines. Possible, probable, and confirmed diagnoses are detailed. The goal is to foster the adoption of a common case definition that will facilitate future research efforts.

Keywords

case definition, clinical diagnosis, wind turbines, adverse health effects, symptoms

Introduction

On the last 3 days of October 2010, a groundbreaking meeting was held in the Waring House situated in Prince Edward County, Ontario (Society for Wind Vigilance, 2010). The focus of the symposium was the emerging issue of adverse health effects (AHEs) being experienced by people living in the environs of industrial wind turbines (IWTs).

These health effects appear to correlate with proximity to IWTs, the sound pressure level emitted by the IWTs, the frequency of the noise, the time of exposure, and individual response. The pattern of individuals' complaints demonstrates a striking similarity internationally in media reports and in physician-generated case series.

The issue of AHEs is of considerable complexity and has excited much controversy between proponents of the wind industry and those who have identified widespread media and Internet reports of AHEs in virtually all countries where IWTs have been erected (Gray, 2010; Jopson, 2010; Lam, 2009; Turkel, 2010).

The IWT proponents claim IWTs to be a promising green, clean, and free alternative source of electrical power and an ideal solution for reducing green house gases (Canadian Wind Energy Association, 2011; Nextera Energy Resources, 2010). Those who are concerned about IWT development too close to residences and who seek to prevent AHEs have a contrary view denying the foregoing claims and questioning the utility and safety of IWTs (Bryce, 2010; Gilligan, 2010).

This article will concentrate on the health aspects and the challenge of a case definition, leaving aside the debate surrounding economics, energy policy, lobbying, and social marketing, although all have a significant impact on government decision making.

Overview of Conference and Speakers

The purpose of the symposium was to promote a multidisciplinary dialogue on possible AHEs in an effort to advance the understanding of the genesis of complaints appearing globally. Among the goals of the symposium was a need to develop a case definition, which had been under discussion since June 2010.

The symposium attracted a multidisciplinary international group of speakers (14), including the disciplines of medicine (four specialties), acoustics, psychology, business, physics,

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epidemiology, policy analysts, pharmacy, law, statistics, and media (Society for Wind Vigilance, 2010). There was also an informal research meeting of the speakers joined by two family physicians and an occupational health physician where a debriefing of the symposium was held and future plans for research made.

Approximately 100 people attended the symposium including municipal and federal politicians, media, documentary filmmakers, as well as two members of a leading consulting group for the industry and two representatives from a wind power developer. There was a notable absence of any representatives from the Ontario provincial government.

Brief Summary of Presentations

The descriptions of the presentations below are highly abbreviated. The reader is referred to the Society for Wind Vigilance's website for more details.

Physics of IWTs and the resultant sound pressure level (SPL) are not adequately or consistently regulated. Based on experience with other noise sources, SPL clearly presents a health risk (Harrison, 2010; James, 2010; Walsh, 2010).

The human ear is perturbed by IWTs in quiet rural areas, potentially leading to neural remodeling and disorganization of neural pathways. It is more likely than not that the symptoms and signs associated with wind turbine syndrome are due to the sound energy emitted by IWTs. Low-frequency noise and infrasound will more likely than not be shown in subsequent research to be playing a major role in the genesis of wind turbine syndrome (Pierpont, 2010).

The outer hair cells of the cochlea respond to low frequency and infrasound. Sonic energy that is inaudible is perceived though not necessarily heard (except in sensitive people). What cannot be heard therefore may produce AHEs. This statement was made by Dr. Alex Salt, referring to his research using the standard animal model (guinea pig) for the study of human hearing (Salt, 2010).

Noise and infrasound during the day are capable of causing mood disorder, cognitive dysfunction, and learning and developmental problems in children. Stress and psychological distress are established findings of chronic exposure to noise. Chronic stress has serious physiological consequences (Bronzaft, 2010).

Nighttime noise compromises restorative sleep. Restorative sleep is a necessary condition for maintaining health and well-being. Chronic sleep disturbances (increased arousals and awakenings) and/or deprivation are established AHEs known to substantially increase the risk for chronic disease and premature death (Hanning, 2010).

Control studies comparing populations living near and far from IWT installations demonstrate a substantial and statistically significant difference in quality of life, mood disorders, and sleep disruption (Nissenbaum, 2010).

More than a hundred people in Ontario have self-identified as having AHEs using the Canada Vigilance protocol. AHEs with a very wide range of complaints were made, of which the most frequent are compromise of quality of life, sleep disruption, some living in the environs of IWTs leaving their homes temporarily or permanently in order to restore their health (Krogh, 2010). While some improvement in health status is achieved, follow-up has revealed that preexposure health status is not necessarily regained.

These findings are significant from a public health perspective for many reasons, including the findings the crossover and revealed preference in the WindVOiCe survey (Krogh et al., 2011). Crossover refers to the phenomenon of exacerbation and amelioration when near and far from wind farms, respectively. Revealed preference describes the act of leaving one's accustomed residence permanently or temporarily for significant periods of time in order to achieve restoration.

Legally there is evidence that the precautionary principle has not been respected by the governments who regulate and approve IWT installations in the absence of medical or health evidence establishing their safety (Gillespie, 2010). There is an urgent need to pursue research establishing dose-response curves as well as clinical research regarding psychological and physiological consequences (Bronzaft, 2010; Hanning, 2010).

There was a clear consensus among the foregoing presentations and from a wide variety of perspectives that AHEs are indeed occurring in relationship to people living in the environs of IWTs. In addition, an emerging consensus was evolving regarding a case definition that could be deployed by experts representing the many diverse disciplines in attendance. The importance of unifying the case definition for the purposes of research and future communications was clear.

Audience Response

The symposium featured a learned and diverse group of speakers as noted above. Attendees were able to witness and participate in a successful event of transdisciplinarity. Regardless of discipline, a unity of perspective was achieved. AHEs are clearly an issue for people living in the environs of wind farms. While the precise mechanism for the cause of AHEs remains to be elucidated, there is enough evidence to conclude IWTs represent a public health threat. Audience members were also highly supportive of a unified case definition.

Summary

The common denominator of the global reports of AHEs is the compromise of quality of life, restorative sleep, and psychological well-being.

There are many reports of AHEs in the environs of IWTs, including several case series (Harry, 2007). Unfortunately, no standard protocol for data gathering has been developed. This has lead to a wide variety of symptoms being reported and documented. This variance is exacerbated by the nonspecific nature of the complaints since the recorded symptomatology can arise from a wide variety of ailments and diseases.

The task of a case definition is to weight the unique elements of AHE/IWT to distinguish the clinical disorder from competing explanations. There are common themes found in the reports that are reflected in the first- and second-order criteria. There are few, if any, alternate explanations for the first- and second-order criteria other than AHE/IWT.

The third-order criteria serve the purpose of capturing the most commonly reported symptoms.

It is hoped that future reports will adopt a standardized protocol based on this case definition, which would facilitate future research and management of AHE/IWT.

Case Definition

The criteria for making an individual diagnosis of probable AHEs in the environs of IWTs are presented in the following paragraphs. The definition endeavors to be specific and sensitive. While the definition has not been validated formally in practice, it has proven useful. The case definition represents an important starting point for future international research collaboration. The genesis of the definition is based on a review of the literature and direct experience with those individuals experiencing AHE/IWT. It has been used to provide guidance to physicians and other primary health providers when they are asked to manage individuals following exposure to IWTs. The value of this proposal is based on the absence of a specific case definition either in the peer-reviewed or gray literature.

Diagnosis of Adverse Health Effects in the Environs of Industrial Wind Turbines

Possible adverse health effects. Report of a change in health status by people living within 5 km of a wind farm installation. Further confirmation is required to validate or exclude AHE/IWT by establishing a medical history that satisfies the criteria identified under "Probable Adverse Health Effects" below.

Probable adverse health effects.

1. First-order criteria (all four of the following must be present):
   - (a) Domicile within 5 km of industrial wind turbines (IWT)
   - (b) Altered health status following the start-up of, or initial exposure to, and during the operation of, IWTs. There may be a latent period of up to 6 months
   - (c) Amelioration of symptoms when more than 5 km from the environs of IWTs
   - (d) Recurrence of symptoms upon return to environs of IWTs within 5 km
2. Second-order criteria (at least three of the following occur or worsen after the initiation of operation of IWT):
   - (a) Compromise of quality of life
   - (b) Continuing sleep disruption, difficulty initiating sleep, and/or difficulty with sleep disruption
   - (c) Annoyance producing increased levels of stress and/or psychological distress
   - (d) Preference to leave residence temporarily or permanently for sleep restoration or well-being
3. Third-order criteria (at least three of the following occur or worsen following the initiation of IWTs):
   - (i) Otological and vestibular
     - (a) Tinnitus
     - (b) Dizziness
     - (c) Difficulties with balance
     - (d) Ear ache
     - (e) Nausea
   - (ii) Cognitive
     - (a) Difficulty in concentrating
     - (b) Problems with recall or difficulties with remembering significant information
   - (iii) Cardiovascular
     - (a) Hypertension
     - (b) Palpitations
     - (c) Enlarged heart (cardiomegaly)
   - (iv) Psychological
     - (a) Mood disorder, that is, depression, anxiety
     - (b) Frustration
     - (c) Feelings of distress
     - (d) Anger
   - (v) Regulatory disorders
     - (a) Difficulty in diabetes control
     - (b) Onset of thyroid disorders or difficulty controlling hypo- or hyperthyroidism
   - (vi) Systemic
     - (a) Fatigue
     - (b) Sleepiness

Confirmed adverse health effects. The confirmation of AHE/IWT is achieved by a clinical evaluation and physiological monitoring of individuals during exposure to IWT sonic energy or an accurate facsimile (recording or other imitative source of IWT sound). Ideally, sleep studies should be carried out in the home of people experiencing AHEs. The complex physiological monitoring equipment required for a sleep study is not readily made mobile. Accordingly, sleep studies need to be carried out in an established clinical sleep laboratory with a source of sonic energy that accurately reflects the person's exposure to IWTs.

The process may be simpler once controlled studies comparing possible victims with a nonexposed matched population are carried out. These studies could help determine the core physiological change(s) that is (are) likely occurring to those who live in the environs of IWTs.

The need to rule out alternate explanations is the responsibility of the licensed clinician. While adherence to the criteria has resulted in no false positive diagnosis to date further validation is required.

Differential Diagnosis

Consideration should be given to other stressors present in the community. The most obvious is the wind itself, which when associated with substantial barometric changes is known to cause a variety of symptoms. In this case, the onset of AHEs would not correlate with the establishment of a wind farm nor would the AHEs improve when leaving the environs of a wind farm.

A second possibility is a stressful home environment, which might lead to restoration being more likely away from home. A history for family stressors should be elicited and ruled in or out. Another distinguishing feature is the absence of correlation with IWTs starting up or being in operation.

Psychological issues and/or mood disorders may be simultaneously or independently present. A key differentiating point is the timing of the onset and the impact of being away from home and the environs of IWTs. Significant improvement away from the environs of wind turbines and revealed preference for sleeping away from home serve to distinguish between AHEs due to IWTs versus an independent cause. If the situation appears more complex then a referral to a clinical psychologist or psychiatrist might be considered.

Apart from the foregoing, there are very few if any imitative AHEs that can meet the three orders of criteria outlined above. However, the author invites critical commentary that might indicate a different conclusion.

Conclusions

1. A multidisciplinary symposium was held to address the possibility of adverse health effects in the environs of industrial wind turbines.
2. There was a consensus (unanimity) among the various experts that more likely than not, adverse health effects are occurring in the environs of industrial wind farms.
3. A case definition for adverse health effects in the environs of industrial wind turbines has been proposed based on the best available evidence. To date it has proven useful in clinical practice.
4. Further research is required to refine and validate the proposed definition and identify the simplest method by which to diagnose a confirmed case.

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Bio

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Mitigating the Acoustic Impacts of Modern Technologies: Acoustic, Health, and Psychosocial Factors Informing Wind Farm Placement

Daniel Shepherd[1] **and Rex Billington**[1]

Abstract

Wind turbine noise is annoying and has been linked to increased levels of psychological distress, stress, difficulty falling asleep, and sleep interruption. For these reasons, there is a need for competently designed noise standards to safeguard community health and well-being. The authors identify key considerations for the development of wind turbine noise standards, which emphasize a more social and humanistic approach to the assessment of new energy technologies in society.

Keywords

wind turbines, community noise, noise standards, health, sense of place

Introduction

The relationship between individuals or groups and their environment can be assessed from one or more perspectives. One approach is environmental psychology, which examines the effect of environmental parameters on the environment's inhabitants. Typically, the sorts of parameters scrutinized are those that are problematic in some way, and which adversely affect the well-being of those individuals found residing or operating within the confines of the environment. One example of a commonly cited environmental problem is noise (Proshansky, 1987), which traditionally has been judged more of a problem in high-density urban areas than rural or semirural (e.g., greenbelt) areas. In the past decade, a new source of noise has emerged in many rural and semirural areas across the world, noise associated with the operation of wind turbines.

Though considered a "green" source of renewable energy, wind turbines have their own environmental and social impacts and need to be sited with care and consideration in relation to the communities hosting them. Communities opposed to wind turbines argue that their health, amenity, and sense of place are compromised by turbine noise and visual impacts. Wind energy proponents argue that wind turbines provide communities with environment-friendly energy and economic opportunities. In between are the authorities overseeing the consent and compliance processes. There has been considerable public and academic debate over whether wind turbine noise poses a significant health threat to those living in their vicinity. It has been suggested that wind turbines can directly affect health via the emission of low-frequency sound energy (including infrasound), though this is currently an area of controversy (Pierpont, 2009; Salt & Timothy, 2010). Additionally, wind turbines may compromise health by producing sound that is annoying and/or can disrupt sleep. In this respect, turbine noise can be classified as community noise alongside industrial and transportation noise. When erected in rural settings, the visual impact of turbines can interact with turbine noise to exacerbate annoyance reactions (E. Pedersen & Persson Waye, 2004) and potentially reduce amenity (Pheasant, Fisher, Watts, Whitaker, & Horoshenkov, 2010).

Noise, as a social problem, is determined by a number of factors, some of which interact, some of which are acoustically related, and others which are not. This makes it very difficult to predict both individual and group responses to noise, which in turn hampers the development of noise standards. Factors influencing social reactivity to noise include the physical characteristics of the noise itself, the characteristics of the environment exposed to the noise (e.g., rural vs. suburban vs. urban), the type of human activities that the noise interferes with (e.g., rest, recreation, sleep, work), and the traits of the exposed individuals. The notion that living in the vicinity of a busy road, an airport, or a cluster of wind turbines can degrade health is, for some, a ridiculous proposition. For others, the invasion of their personal spaces by intrusive noise constitutes

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an abuse that severely degrades general health and well-being. This variability in response at the human level renders noise level an inadequate metric with which to safeguard community health, and in fact subjective evaluations of noise (e.g., intrusive, unnecessary) constitute a better predictor of aversive response than the noise itself (Flindell & Stallen, 1999). However, the inclusion of the human and social sides of the equation into noise guidelines remains an ongoing challenge (Maris, Stallen, Vermunt, & Steensma, 2007), and this criticism extends to noise standards that have "arguably" been developed to protect society from wind turbine noise. In this monograph, we list a number of points relevant to the placement of wind turbines near inhabited areas. The first cluster of points (Points 1 to 14) is general in nature, whereas the second cluster (Points 15 to 20) relates specifically to noise standards.

1. Wind Turbines Emit Noise

Noise is an unwanted sound that is judged undesirable, irritating, discordant with ones expectations, and/or that interferes with wanted sounds. Annoying or intrusive sound emanating from road, wind turbines, rail and air traffic, industries, construction and public works, or the neighborhood is known as community noise. Community noise is classified by the World Health Organization (WHO; 2011) as a common pollutant and health threat. Whether sited in isolation or in clusters, wind turbines produce audible sound to those living in their close vicinity. What distance defines "close vicinity" has yet to be determined, though Di Napoli (2011) reports that amplitude-modulated turbine noise can be heard up to 4 kilometers away from the source. Irrespective of distance, however, if the sound annoys, or disturbs the sleep of an individual, then the turbine(s) can be classified as noise generator(s).

People respond more negatively to man-made noise than natural noise (Nosulenko, 1990; E. Pedersen & Persson Waye, 2008), though some developers and supporters of wind energy claim that the sound emitted by wind turbines is congruent with natural habitats and is aesthetically pleasing. Sometimes developers and their contracted acousticians will compare wind turbine sounds to rustling leaves, flowing streams, or lapping waves. It follows then from these comparisons that turbine sounds cannot be considered noise in the formal sense as people generally do not find such sounds annoying or disruptive to sleep. In fact, the little research that has been undertaken on the sound properties of wind turbines concludes just the opposite (Pheasant et al., 2010; F. van den Berg, Pedersen, Bouma, & Bakker, 2008). Therefore, it must be acknowledged that wind turbines have the capacity to emit noise.

2. Spectrum Analyzers and Noise-Level Meters Do Not Mimic Human Hearing

Some acousticians mistakenly believe that if a band of acoustic frequencies are not represented in physical measurements of acoustic energy (e.g., on a spectrograph), then those frequencies cannot be perceived. However, for humans hearing is the most acute sense, and in controlled conditions a person with normal hearing can detect vibrations with an amplitude of less than half a nanometer: approximately one tenth the diameter of the hydrogen atom (Green, 1976). The range of sounds a properly functioning human ear can detect is likewise impressive, ranging from the smallest perceptible amplitude to amplitudes that are 10,000,000,000,000 times greater. Pertinently, our hearing processes are finely tuned to extract correlated patterns of acoustic activity from background noise and can far outperform any current technological devices claiming to perform the same function. Thus, wind turbine noise may be audible to a human even when the noise itself is lower than the ambient noise level (R. H. Pedersen, Von-Hunerbein, & Legarth, 2011; Siponen, 2011) and beyond the resolving power of modern equipment. Therefore, the limits of sound measurement apparatus relative to those of the human auditory system need to be acknowledged when judging acceptable limits of exposure to wind turbine noise.

3. The Subjective Nature of Noise

It has long been recognized that what is, and what is not, noise is highly subjective, and one person's noise can be another's music. Thus, noise pollution must be viewed as comparative to a certain extent, with substantial individual differences existing in relation to personal perception, sleep disturbance, annoyance, social context, and perceived control. As with other noise sources, we should expect individual variation with regard to the effects of wind turbine noise. However, it is a fallacy to argue that because only some suffer adverse effects while others do not, those who claim to be suffering effects must be "making them up." In the field of epidemiology, the differential susceptibilities of individuals are known as risk factors, and assuming that individuals of a population can be represented by the average characteristics of the population is known as the ecological inference fallacy. Although the WHO does acknowledge the existence of vulnerable groups, the noise levels presented in its Night Noise Guidelines for Europe (WHO, 2009) nevertheless rest on aggregate data that for the most part do not distinguish vulnerable from non-vulnerable groups. Such an approach, regrettably, constitutes an ecological inference fallacy.

Substantial individual differences are expected, and indeed found, when examining the effects of community noise on humans (Maris et al., 2007), including wind turbine noise (E. Pedersen & Persson Waye, 2008). Unfortunately, for policy makers there is no proportional relationship between annoyance or sleep disturbance and noise level, as these outcome factors will be influenced by characteristics associated with both the noise and the listener (Flindell & Stallen, 1999). Therefore, moderating factors, which include age, noise sensitivity, attitude, social context, coping styles, and mental health, need to be acknowledged and accounted for when judging the appropriateness of wind turbine sites close to residences.

4. Understand the Meaning of Health

Before considering any possible impact of wind turbine noise on health, an acceptable definition of health must be adopted. Such a task is not laborious however, as the WHO did precisely that during its formation in 1948. The WHO (1948) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

Thus, health refers not only to illness and "cuts-and-bruises" but also to well-being, quality of life, and amenity. In its 2008 World Health Report, the WHO recommitted itself to the concept of primary health care and acknowledged that good health exists not in the hospital but in society at large. At the social level, good health can be facilitated not only by the pursuit of healthy lifestyles (e.g., exercise and diet) but also by the provision of restful and restorative living environments (e.g., soundscapes). A prominent factor determining the restfulness of a living space is the level of privacy and intrusion by pollutants, including smell, air quality, and noise. In assessing the impacts of wind turbine noise, it is important to not only consider the potential of wind turbine noise to induce poor health but also its potential to compromise good health.

The health of a nation or group may be assessed using morbidity and mortality data and by using health status and health-related quality-of-life (HRQOL) data. The latter two approaches correlate highly with medical morbidity assessment, but instead of diagnosing particular symptoms or classifying health problems as the medical profession would, this approach has the value and advantage of examining factors that cause and/or result from a health disorder(s). These factors include physical health, psychological well-being, social support, and the environment. Such information is important both in the prevention and the treatment of health problems and in the assessment of treatment outcomes. It is now common practice in health research to incorporate measures of HRQOL, such that the U.S. Food and Drug Administration agency, for example, insists on such assessment in appraising all new pharmaceutical products (Glasgow & Emmons, 2007). Therefore, health status and HRQOL instruments would serve well to the studies of the effect of wind turbines on the health and well-being of nearby residents and in many ways are more practical and sensitive measures than those applied in medical appraisals.

5. Avoid the Argumentum Ad Ignorantiam

Wind turbines are a new source of community noise and as such their effects are only beginning to emerge in the literature. The recognition of a new disease, disorder, or threat to health usually follows a set pathway. First, doctors and practitioners attempt to fit symptoms into predefined diagnostic categories or else classify the complaints as psychosomatic. Second, as evidence accumulates, case studies begin to appear in the literature and exploratory research is undertaken to obtain better descriptions of the symptoms/complaints. Third, intensive research is undertaken examining the distribution and prevalence of those reporting symptoms, the factors correlating with the distribution and prevalence of those symptoms, and ultimately to cause-and-effect explanations as to why those reporting symptoms may be doing so.

Currently, the health and amenity impacts of wind turbines are only beginning to be elucidated and is caught somewhere between the first and second stages described above. Case studies (e.g., Harry, 2007; Krogh, Gillis, & Kowen, 2011; Pierpont, 2009) and correlational studies (e.g., E. Pedersen & Persson Waye, 2007; F. van den Berg et al., 2008) have already emerged in relation to the health effects of wind turbine noise, indicating that wind turbine noise, like traffic or aviation noise, has the potential to affect health and well-being. We can expect that, over the next decade, intensive research will be undertaken enabling more certain decisions to be made regarding wind turbine noise and health and the mechanisms that mediate the relationships between the two. Until that research is undertaken, however, an absence of data addressing cause-and-effect mechanisms does not equate to an absence of wind turbine noise impact (viz., *argumentum ad ignorantiam*).

6. Critically Interpret the Research

It is important to note that many studies reporting noise annoyance data are laboratory, as opposed to field, studies. If noise guidelines are informed by research predominantly undertaken in laboratories then they themselves lack ecological validity. That is, what is measured in a laboratory may not concord with measurements made in the actual environment. Additionally, older published data on wind turbine noise may involve turbines that are substantially fewer in number, smaller in size, and less noisy than modern wind turbine set ups, and so present findings that cannot be generalized to contemporary technology. Wind turbine noise research (actually nonsystematic literature reviews) has been conducted by industrial stakeholders in wind energy (e.g., Colby, 2009), which present results that likewise should be interpreted with caution. Wind turbine noise research, then, should be consulted with qualification and critique when considering wind turbine effects and not taken prima facie.

7. Determine Why Turbine Noise Is Especially Annoying

The characteristics of wind turbine noise have been well described from a social perspective (e.g., F. van den Berg et al., 2008, Table 7.23), either as a typical amplitude modulation (i.e., a 3-5 dB modulated "swish," audible in the near field) or an atypical amplitude modulation (i.e., >5 dB modulated "thump," audible in the far field). G. P. van den Berg (2004) shows that wind turbines produce noise with an impulsive character, and although the actual cause of the swishing or thumping has not yet been fully elucidated, it has been demonstrated that this swishing or thumping pattern is common with larger turbines (Stigwood, 2008) and may result from a fluctuating angle of attack between the trailing edge of the rotor blade and wind (Siponen, 2011). Furthermore, lower frequencies, which tend to be judged as more annoying than higher frequencies, become more salient during the transitions from swish to thump. In the far field, the less common two-bladed turbines, it should be noted, have a different noise profile characterized by an alternating thump without the swish.

Because wind is variable and not constant, wind turbine noise levels are also variable and inconsistent. Furthermore, the cyclic action of the turbine rotors serves to modulate noise level across time, producing a noise that can be perceived as repeating itself several times per second. This is unfortunate, as human senses act as contrast analyzers, responding to changes in sound rather than to the absolute level of the sound itself (Laming, 1986). Additionally, we are more sensitive to change in continuous noise (such as impulsive turbine noise) than to discrete auditory events (e.g., a passing car at night). Thus, wind variability will bring about noticeable changes in the level of turbine noise, irrespective of the aggregated level of that noise, and these changes in noise level due to wind speed fluctuations will make the noise more noticeable, especially so at night, when ambient sound levels reduce. Consequently, overall measures of sound level are not in themselves useful in predicting annoyance if those levels are dynamic (i.e., they change over time). In fact, the level of noise only explains 10% to 25% of an individual's response to noise (E. Pedersen & Persson Waye, 2008). When considering acoustical characteristics of turbine noise, however, overall noise level is usually chosen as the metric of importance whereas other aspects of the noise such as periodic amplitude modulation are ignored (Lundmark, 2011). Metrics describing the amplitude modulation characteristics of turbine noise, such as that proposed by T. H. Pedersen et al. (2011), should therefore be considered when judging the appropriateness of turbine placements.

8. Have Experts Working Within Their Field of Expertise

Although the contribution of acousticians can be critical in the measurement of noise at the physical level of description, there has been a noticeable trend in the field of public policy that, when the effects of wind turbine noise on society are being debated, acousticians are adopting the role of health experts. British physician Dr. Amanda Harry (2007) reports the alarming prevalence of acousticians giving evidence with regard to the health effects of sound emitted from wind turbines. She states that their "comments are made outside their area of expertise and should be ignored until proper medical, epidemiological studies are carried out by independent researchers" (p. 21). The message here is that acousticians reporting measured or predicted wind turbine noise levels should withhold commentary on likely health effects unless possessing suitable qualifications and can support their recommendations with quality research. As a corollary, health experts should not be commenting on acoustical matters without relevant qualification and the backing of quality research.

9. Reliance on Oversimplified Models

Though noise level itself explains only a small proportion of the variability found in the response to noise, it invariably carries the greater weighting and emphasis during wind turbine consent processes. Noise level metrics are usually predicted, though on occasion may be reported from other wind farms of a similar nature to that proposed or directly from the manufacturer's testing facilities. In relation to predicted levels, there are a number of factors influencing the predictions, and failing to sufficiently account for these factors can potentially produce either under- or overestimates of turbine noise. For example, depending on terrain and time of day, the effects of meteorological conditions on wind turbine noise can be in the order of 20 to 25 dB, with noise levels typically higher in spring than autumn due to temperature differences (Larsson & Öhlund, 2011). Terrain type is also important, and the predictions between open field and forest areas can differ by as much as 20 dB SPL, due to temperature and wind speed differences (Johansson & Almgren, 2011). Additionally, when the terrain impedes the wind close to dwellings then the wind's masking effect is reduced, and turbines located on higher ground may become more audible (Appelqvist & Almgren, 2011). Turbine noise depends on wind speed, which itself peaks between noon and 2:00 p.m. We can conclude that during this time of day the masking efficacy of wind is at its peak. Furthermore, thermal effects on atmospheric stratification can induce significant variability in wind gradients. Hence, wind speed can differ between ground and turbine hub height. Unfortunately, the most common reference of wind vertical profile used in modeling (IEC 61400-11) is appropriate only for flat terrain containing simple vegetation (Gianni, Bartolazzi, Mariani, & Imperato, 2011). Another important factor affecting noise level is the humidity- and temperature-dependent air absorption coefficient, in which lower values (e.g., 0.003 dB/m) yield more conservative estimates than higher values (e.g., 0.005 dB/m). Though these differences may appear subtle, selecting representative air absorption coefficient values are important as propagation through the air introduces random phase shifts due to atmospheric turbulence, which in turn influences noise levels. Additionally, when selecting an appropriate frequency weightings (e.g., dB(A) vs. dB(C)), one must consider that atmospheric sound absorption is greater for high as opposed to low frequencies (Siponen, 2011).

Current approaches to the modeling of sound propagation between multiple turbines assume statistical independence and sum the individual outputs of turbines in order to profile the impact of groups of turbines. Often this involves using manufacturer's technical data from a single turbine, but does not take into account the fact that multiple deterministic noise sources can add coherently. In the case of wind turbine installations, these noise sources include periodic modulating blade noise, low-frequency pulsations, and tones emanating from mechanical processes (Walker, 2011). The interactive effects of turbines may produce local "hotspots" or "heightened noise zones" (Bakker & Rapley, 2010) in which turbine noise can be amplified (and elsewhere attenuated) due to the superposition of multiple turbine acoustic waves. Hence, when predicting turbine noise levels using mathematical models, model complexity should not be sacrificed to simplify the calculation process.

10. Choosing the Right Metric

Another important factor when measuring or predicting wind turbine noise level is the range of exposure levels, that is, the minimum and maximum levels that are emitted by wind turbines. Noise measures based on energy summation and expressed as averaged values are not always sufficient when examining the health-related effects of noise. The WHO (1999) has repeatedly emphasized the importance of measuring peak values of noise fluctuations rather than averages. The inclusion of maximum levels is important as studies have consistently demonstrated that sleep disturbance is related to peak noise levels rather than aggregated measures (Morrell, Taylor, & Lyle, 1997). Thus, any measured or predicted noise levels used by acoustic experts must be accompanied by maximum levels, as sensitivity to the peaks of modulating noise waves are likely to better predict annoyance (Walker, 2011). Bolin and Karasola (2011), arguing against the use of aggregated measures when undertaking monitoring, claim that in order to present a "worst-case scenario," distributions representing the top 10% of the time average levels measured (i.e., dB LA_{10}) should be generated.

Further debate centers on the type of weighting that should be applied to noise measurements and predictions. Currently, standard practice in the wind turbine industry involves using A-weighted noise level estimates (i.e., dB(A)), though these may underestimate annoyance by failing to account for the degree of temporal variations and low-frequency content the measured noise contains. Siponen (2011), accounting for amplitude modulation and the low-frequency noise components in turbine noise, argues that A-weighted noise predictions underestimate the minimum distance required between wind turbines and inhabited dwellings. Instead, he advocates the use of a C-weighting, or else a corrected level based on the difference between C- and A-weightings.

Prior to the approval of a wind farm, it is common practice to assess the ambient (or background) sound levels and to compare these to, or combine them with, the predicted levels. Even this stage of noise level measurement has issues that require consideration, as extraneous factors such as time of year or equipment type can result in substantial overpredictions of ambient noise levels, up to 17 dBA in one study (Terlich, 2011). Seasonal effects such as insect noise can be lessened using weighting algorithms (Terlich, 2011), while decreasing the averaging time from the 1 minute recommended by IEC 61400-11 to around 10 seconds can help eliminate data contaminated by bird cries, pedestrian noise, or traffic noise (Ishibashi, Imaizumi, Ochiai, Inoue, & Yamada, 2011). Arguably, however, smaller durations around 100 milliseconds should be adopted as best practice, as the time averaged dB(A) levels recommended by the IEC 61400-11 (but see also its Appendix A5) fail to measure the amplitude modulation inherent in turbine noise (Lundmark, 2011).

11. Be Critical of Dose-Response Relationships

Many international standards for acceptable levels of community noise are based on the dose-response curve. This approach to establishing acceptable noise levels lacks validity and has been rightly lambasted by acousticians and health researchers alike (Fidell, 2003). The dose-response curve, constructed from dose-response data, plots (for example) noise annoyance as a function of noise level. Users of a dose-response curve define a level of noise annoyance that they are willing to accept and then, either graphically or numerically, derive a threshold by determining the level of noise that yields this predefined annoyance level. Figure 1A illustrates an actual theoretical dose-response curve produced by the Federal Interagency Committee on Aviation Noise (FICON) in the United States. Figure 1B is the same curve but with a shortened *x*-axis (now from 57 to 68 dB) accompanied by actual measurements of noise annoyance for aircraft noise. Note the incompatibility of the theoretical curve and the empirically derived data (data extracted from Fidell, 2003).

As Figure 1B shows, annoyance reactions to noise vary substantially and do not appear to be correlated with noise level. It can be concluded that the high variability between individuals and groups makes it difficult to model the relationship between noise and annoyance. Even though noise level is not a major determinant of noise-induced annoyance responses, plots such as Figure 2 are still used to determine acceptable noise levels. We can conclude from such data that the concept of a simple stimulus-response relationship is inadequate, and more attention needs to be paid to psychosocial factors when assessing the impact of wind turbine noise.

12. Dose-Response Curves and Criteria of Acceptable Harm

Using dose-response curves entails the establishment of an "acceptable harm" threshold, expressed in physical levels of the stimulus. The question is, at what level of noise does one estimate the threshold? In Australia, the criterion for aircraft noise is set at a point in which no more than 10% of the population would be severely affected. However, such criteria setting reflect a utilitarian approach to public health that is simply not sanctioned by modern society and are often arbitrary. Would we put an additive in the water that would benefit 90% of citizens and make the other 10% ill? These values need to be based on scientific validity and medical evidence but instead

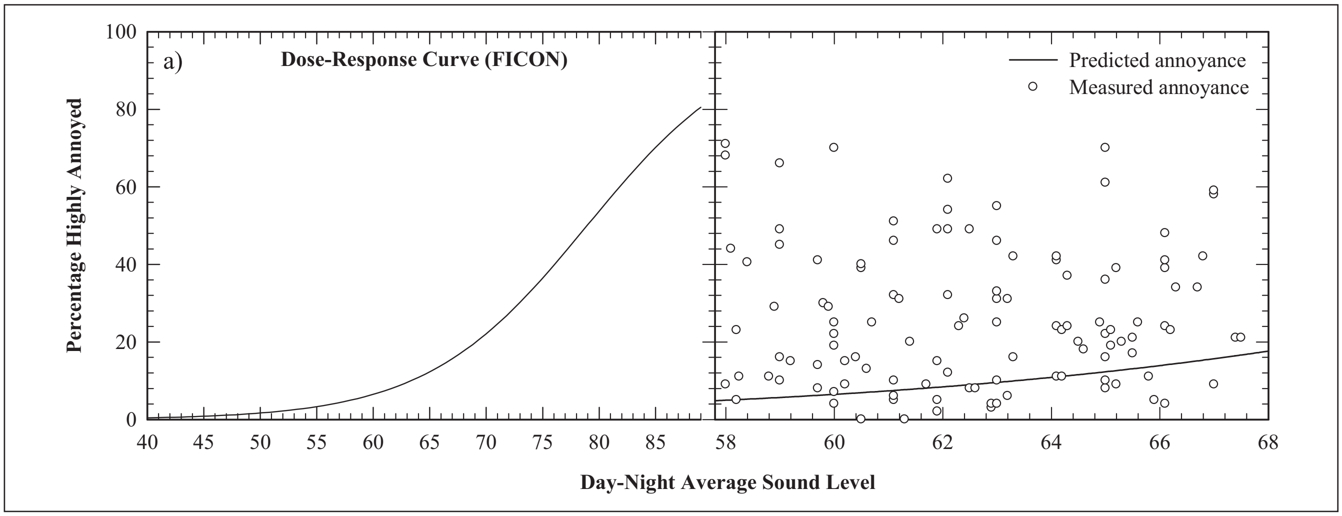

Figure 1. The dose-response function adopted by FICON (1992) to determine acceptable aviation noise levels (A) and actual measurements of aviation noise-induced annoyance in the vicinity of 60 and 65 dB LDN (B)
Note. Data reproduced with permission from Fidell (2003).

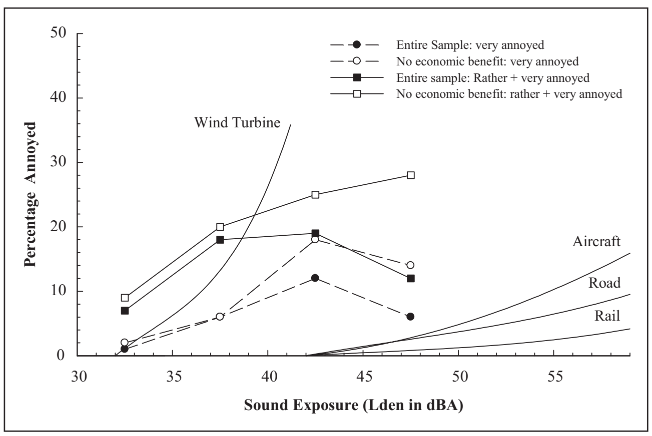

Figure 2. Annoyance plotted as a function of noise level for four theoretical models (rail, road, and air parameters: Miedema & Oudshoorm, 2001; wind turbine parameters: E. Pedersen & Persson Waye, 2004) and four sets of data obtained from Van der Berg et al. (2008, Tables 7.24 to 7.26)
Note. For the data, closed symbols are for the entire sample, whereas open symbols are for those who identified that they had no economic interest. Circles represent the percentage of "very annoyed" responses whereas squares represent the sum of "very annoyed" and "rather annoyed" responses.

are being set to reflect industrial objectives. The notion of acceptable harm then is one that needs to be debated at the societal level and, in relation to wind turbine noise, defined on a case-by-case basis with input from the communities hosting the turbines.

13. Noise Is a Social Problem, So Consider Approaches Other Than Level

Adopting noise level as the sole criterion of health impact makes little sense, given that (a) noise level is a poor predictor of the human response it elicits and (b) there has been a systemic failure in the prediction and measurement of wind turbine noise. In relation to the later, it is apparent that errors of prediction and measurement emerge due to inadequate methodology. For example, many of the wind turbine installations erected in New Zealand's Manawatu region were initially welcomed by residents who supported renewable energy (Martin, 2008). However, this initial enthusiasm was based on reassurances from the developers that turbine noise would not intrude into homes. The resulting lack of concordance between the predicted impacts of the noise and the actual impacts of the noise has since led to a rise in resistance to wind turbines in this region. Further evidence comes from a recent compliance report (Lloyd, 2010) undertaken on the Te Rere Hau wind turbine installation, also in the Manawatu region, that indicates that the complaints made by nearby residents regarding noise exposure are justified on the basis of recent noise level readings. Note that these readings are discordant with those originally predicted and do not comply with the original resource consent conditions. In 2011, court action against the wind farm operator was initiated by the Manawatu District Council.

Because of the discrepancies between predicted and actual noise levels, it may be more prudent to rely on evidence coming from individuals at established wind turbine installations than mathematical models heavily constrained by assumptions (see Points 9 and 10). Additionally, social-based approaches to wind turbine siting have actually been reported in the peer-reviewed literature (e.g., Gross, 2007; Maris et al., 2007), though incorporating these approaches into noise standards remain a challenge. Some countries, including Britain, Germany, and Canada, have negated noise level criteria and have instead adopted minimum setback distances between turbines and residential buildings. At this point in time, however, the use of setback distance is as controversial as the use of noise levels due to the lack of informing data.

14. Public Relations Should Consider the Social and Cultural Context

Invariably, the deployment of wind turbines creates winners (those who economically benefit) and losers (those who do not benefit and see the turbines as pollutants). Thus, it is important that the decision-making processes be perceived by all involved to be fair, or divided communities may ensue resulting in damaged relationships, degraded social well-being, and loss of sense of place. To this end, wind farm developers should not adopt an aggressive approach to decision-making processes, because in the past this has led to pronounced community divisions (Gross, 2007). Nor should they outwardly exploit their economic and political advantages over local opposition, as perceived procedural unfairness lessens social acceptance.

Maris et al. (2007) demonstrate that perceptions of procedural unfairness during the decision-making process, and insensitivity to the social context, can serve to increase subsequent noise-induced annoyance when the noise begins. Thus, public relations between developer and community can critically affect annoyance responses. An example of strained relationships within a community, and between community and wind turbine developer, can be found with the development of the Makara Wind Farm immediately north of Wellington, New Zealand's capital city. As part of the consent process, the developer was required to install a complaints line for the community to call if the noise became excessive. Thousands of calls were received in the first year, but the complaints themselves were never acted upon. A year later the wind turbine developer proposed to increase the wind farm into an adjacent area, which was opposed by the Makara Valley community. At subsequent consent hearings, the developer employed a marketing company to analyze complaints line data and use it against the Makara community. Such behavior resulted in indignation from the Makara community and would have likely increased annoyance to noise produced by the wind turbines already in operation.

The Use and Misuse of Noise Standards

A technical standard is a recognized norm or requirement, usually a formal document describing a standardized criterion, method, process, or practice. Standards may be developed at an international level, in which case they are classified as international standards, or locally by individual nations, in which case they are national standards. The process of agreeing to a technical standard is known as standardization. Standards have been an unqualified success in the field of engineering, science, and commerce. To stipulate a standardized procedure, test, definition, or specification is akin to creating a common language or frame of reference that facilitates communication and understanding between diverse groups. Noise standards exist to protect the public from noise and governments (local or central) from litigation and generally consist of regionally developed standards. That different nations have different noise standards indicates the impact of sociocultural and sociopolitical factors on noise acceptance. Because of their recent introduction, at least relative to other noise sources, wind turbines have developed rapidly in character, and consequently the development of noise standards specific to turbine noise has, for this reason and others besides, lagged.

The existence of a standard does not, unfortunately, presuppose that the standard itself is the correct procedure, test, definition, or specification. Nor does it guarantee that the standard is actually useful or effective. In fact, noise standards are evolving entities that are constantly undergoing review and change. In relation to noise and the public good, the WHO (1999), in identifying the inadequacies of noise emission standards, reports that existing trends in noise pollution are unsustainable. That noise standards are not necessarily definitive is further demonstrated by the lack of agreement that can exist among experts on standards or differences between standards. The differences of opinion surrounding the revision of the New Zealand standard for acceptable wind turbine noise (NZS6808) is testament to this (see, e.g., Chiles, 2010; Dickinson, 2009).

The classification of noise into broad ranges of frequency (e.g., low, medium, and high frequency) likewise illustrates the relative nature of noise standards. There appears to be a lack of universal agreement on this matter, and there are different standards in Germany (DIN 45680:1997), the United States of America (ANSI S12.9), Sweden (SOSFS 1996L17), and both Denmark and Holland. Given that the frequency content of the turbine noise is a contentious issue, and one that acousticians debate with some vigor, it can be argued that a common language is needed in order to advance these debates. In relation to the measurement of low-frequency noise, the international ISO-140-5 and the Swedish SP Info 1996:17 standards predict different noise level differences between outside and inside values (Lindkvist & Almgren, 2011). Thus, although useful, standards should not be treated as definitive authorities on where (or where not) wind turbines can be placed. A number of points relevant to the wind turbine noise standards are now made.

15. Standards Based on Standards

One can often encounter a Russian doll–type situation when examining noise standards, with many noise standards referencing other standards (which in turn may reference other standards) that may themselves not be fit for the purpose. For example, the international standard ISO9613 (Acoustics—Attenuation of sound during propagation outdoors) is used extensively in turbine noise standards (e.g., NZS6808:2010), yet it has been found to be inaccurate when applied to wind turbine noise (Bolin & Karasalo, 2011; Johansson & Almgren, 2011). It is thus of utmost importance to decompose standards into their constituent authorities and to examine each individually. The consequence of a noise standard relying on other inappropriate or ineffectual standards can result in flawed noise level predictions or inaccurate noise level readings during monitoring.

16. Reduce the Lag Between Practice and Reality

Technical and health standards are not updated quickly enough and perpetually lag behind research and technological developments. In England, wind turbine noise is predicted and assessed using standards that were developed for substantially shorter wind turbines (Davis, 2007). The WHO (1999), in their publication "Guidelines for Community Noise," acknowledges that their own noise recommendations are a work in progress and that there is still much to be done. Recently, there were calls from acoustical experts to update current American noise standards (Kryter, 2007), while an investigation by the Department of Health and Aging in Australia (Enhealth, 2004) has called for an immediate review of all noise guidelines, standards, and policies in light of the adverse health outcomes being associated with community noise. Thus, noise standards should have regular reviews in which they are updated, if necessary, to reflect technological advances and the latest findings in the field. For example, the period between the release of the New Zealand wind turbine standard (NZS6808:1998) and its revision (NZS6808:2010) is arguably too lengthy given the volume of research published during this period. Worse still is the British standard ETSU-R-97, which, despite being obsolete and there being repeated calls for a revision, remains in use.

17. Manage Conflicts of Interest

In some countries noise standards can be industry sponsored and as such lack sufficient input from stakeholders, social scientists, and health professionals. Failing to sufficiently declare conflicts of interests of those developing wind turbine noise standards can result in standards being endowed with more credibility than they deserve, or at a later date having their credibility impeached. Thus, all reasonable effort should be made to balance out groups involved with standard development, and all conflicts of interest should be explicitly declared. Wind turbine noise standards containing statements on acceptable noise levels should be developed with input from social organizations concerned with noise levels (e.g., the noise abatement society), and should clearly acknowledge that as a social problem, the mitigation of noise annoyance must necessarily include social factors.

18. The Nonequivalence of Noise Standards

When developing wind turbine noise standards, it is important that preexisting standards developed for other noise sources (e.g., road, rail, aviation) be applied with caution and qualification. For example, the Night Noise Guidelines for Europe developed by the WHO (2009) are based predominantly on road and aviation traffic data, yet are commonly cited in wind turbine consent applications. However, the unique physical characteristics of wind turbine noise (i.e., amplitude modulation), and the characteristics of those communities commonly exposed (i.e., rural and semirural dwellers), dictates that wind turbine noise is consistently judged more annoying than road, rail, or aviation noise (see Figure 2). The data plotted in Figure 2 suggests that the application of noise guidelines derived from aircraft, road, or rail data such as those published by the WHO should be accompanied by a 10 decibel (or more) subtraction in order to normalize it to the turbine context. In Italy, a generic national standard from noise regulation exists (DPCM 1/3/1991) that is not specific to turbine noise and is clearly inadequate to regulate the latest advances in turbine technology.

19. Domain-Specific Expertise

Wind turbine noise guidelines are often developed by teams of acousticians focusing on the physical measurements of noise, who later participate in the drafting of health impact clauses almost as an afterthought. For example, the aforementioned revision of the New Zealand standard (NZS6808:2010) had only a small proportion of health experts, and possibly as a result of this, only a small proportion of the standard was dedicated to health. We suggest that, regardless of noise source, measurement methodologies should be contained within a unique standard separate from those standards assessing health impacts. This would ensure that both measurement and health risk protocols would be developed by the experts in the field, and as such be fit for purpose.

20. Standards Are Not Weapons to Suppress Social Concerns

Noise standards can ironically be used to suppress "unwanted noise" coming from communities dissatisfied with noise levels. Giving a New Zealand example, a major regional newspaper (*The Manawatu Times*, 2005) reported the following statement from the owner of a newly established wind turbine installation: "It's a small number of people making a big noise about nothing" in response to locals complaining of a rumbling sound that "bombarded us with noise and vibration." The wind farm operator justified these comments on the basis of the advice they had received from their employed "health consultants," who were in fact acousticians providing information far beyond their expertise. These consultants justified their judgments by appealing to New Zealand's wind turbine noise standard (NZS6808), which had been sponsored and largely developed by umbrella organizations funded by wind turbine developers, including the owner.

Conclusion

Currently, environmental agencies, planning authorities, and policy makers in many parts of the world are demanding more information on the possible link between wind turbine noise and health in order to legislate permissible noise levels or setback distances. Concurrently, larger and noisier wind turbines are emerging, and consent is being sought for progressively larger wind turbine installations to be placed even closer to human habitats. However, the stimulus-response approach demanded by the bulk of these decision makers is misguided, and neither noise levels nor setback distances used in isolation are likely to be acceptable by society at large. Although noise standards can effectively and fairly facilitate decision-making processes if developed properly, the current standards on offer suffer severe conceptual difficulties. All this points to a need to incorporate social perspectives into the decision-making processes, though how this process itself can be standardized remains a challenge (but see Gross, 2007; Maris et al., 2007).

We have listed a number of important considerations that need to be addressed by environmental agencies currently deciding on the location of wind turbine installations. These various considerations can be grouped into broader categories, such as the credibility of procedures and players involved with standard development, the use of research to inform standards, critique of current approaches inherent in contemporary noise standards, and broader social factors. Ultimately, however, man-made noise is rarely perceived in a social vacuum (Maris et al., 2007), and acceptable levels of wind turbine noise should be a societal, and not a technological, decision one.

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Public Health Ethics, Legitimacy, and the Challenges of Industrial Wind Turbines: The Case of Ontario, Canada

Martin Shain[1]

Abstract

While industrial wind turbines (IWTs) clearly raise issues concerning threats to the health of a few in contrast to claimed health benefits to many, the trade-off has not been fully considered in a public health framework. This article reviews public health ethics justifications for the licensing and installation of IWTs. It concludes that the current methods used by government to evaluate licensing applications for IWTs do not meet most public health ethical criteria. Furthermore, these methods are contrary to widely held fundamental principles of administrative law and governmental legitimacy. A set of decision-making principles are suggested to address this situation that are derived from existing and emerging legal principles in Canada and elsewhere. These include the Precautionary Principle, the Least Impactful Means (Proportionality) Test, and the Neighbor Principle.

Keywords

public health ethics, wind turbines, legitimacy of government, licensing, decision rules

Introduction

The rationale for governmental support of industrial wind turbines (IWTs) as a viable form of alternate energy production emphasizes their "green" qualities. These qualities are said to include public health benefits because IWTs are claimed to produce less pollution than conventional energy sources. Consequently, we are told to expect less disease burden on the general public from IWTs than from fossil sources.

This assertion has been challenged in articles appearing in this issue (e.g., Bryce). Therefore, to this extent, the public health rationale itself must be reexamined.

But even if the net population health impact of IWTs were to be as claimed by their advocates and proponents, there is still a major problem with the rationale. This problem is only exacerbated by lack of data to support the green claim.

The problem is that even if the pollution-related public health *benefits* were established, there are also clear public health *risks* associated with IWTs. These risks accrue to a subpopulation of our society that suffers a range of negative health effects from IWTs, as documented in this issue.

The fact that such risks exist at all summons up a need for a risk-benefit analysis, which leads us into the deep waters of arguments predicated on utilitarian and contractarian principles.

The pursuit of these ideas leads us even further into a more fundamental debate on the nature and role of consent to governmental actions. Inevitably, this is the threshold to the very essence of political legitimacy.

In this article, the discourse of public health ethics will be used to parse arguments for and against IWTs in the broader context of governmental legitimacy.

A derived ethical/legal framework is proposed to help inform decision-making processes in governmental and commercial-industrial environments concerning the licensing and installation of IWTs.

Public Health Ethics

While some accounts of public health ethics see the mandate of public health as the maximization of welfare, other just as cogent accounts see it as an aspect of, or means of, producing social justice (Powers & Faden, 2006).

Both accounts, however, involve providing answers to the question: For whom is public health good?

This question assumes greater significance once it is acknowledged that many public health initiatives involve gains to some at the expense of losses to others in a context of

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governmental action backed up by the reality or threat of coercion. Familiar examples include the regulation of smoking, the required use of seat belts and helmets, immunization, and quarantine.

Sometimes, as in the case of wind turbines, the trade-off can be seen as one between asserted population health gains (e.g., net reductions in cases of fossil fuel induced respiratory and lung diseases) and negative impacts on the health of some individuals in specific communities (e.g., sleep loss induced states of anxiety, depression, headaches, extreme fatigue, diminished ability to concentrate, nausea, and other physiological effects including, albeit rarely, vibro-acoustic disease).

The descending gradient between impact on population health and individual health can be in some ways characterized as one of moral ascension: Some might argue that it is more obvious and heinous to expose a few to known immediate hazards in the service of the many who are presumed to benefit in the future from broadly applied social policies such as the proliferation of IWTs.

This type of trade-off, whether consciously or unconsciously applied, raises concerns about social justice and the fair distribution of benefits and burdens. But it has also been said that the conflation of public health with social justice blurs boundaries to such an extent that it ceases to have legitimacy as a definable discipline. As Faden and Shebaya (2010) state,

> One worry raised by this interconnectedness across spheres of social life and policy is that classifying something as a public health matter could be an effective way of taking it out of the realm of legitimate discussion. If the goal of protecting health is seen as clearly good, government actions aimed at securing health may be less scrutinized than actions aimed at more controversial ends, leaving public health officials with too much power and too little democratic accountability. . . . Public health ethics has to give serious consideration to the question: how exactly should the mandate of public health authorities be specified such that they do not run afoul of the requirements of legitimacy in a democratic political system? (p. 7)

This statement, however, raises a further issue to which it will be necessary to return in this article more than once. That is, although IWTs present public health issues, they are not regulated by public health agencies. Consequently, the concern raised by Faden and Shebaya (2010), while poignant in its own right, becomes even more worrying when the very protectors of public health are not even allowed into any kind of official debate about the impact of IWTs.

The following is an account of the ethical justifications typically used in connection with public health measures. Faden and Shebaya (2010) are drawn on for the organization of this section and for the basic outline of justifications used in public health ethics.

It is important to note that the need for justification arises often not from across the board concerns that public health measures may be illegitimate in some way so much as from a more particular concern that certain measures affect some members of society in adverse ways or that they benefit some at the expense of others.

Note too that the justifications outlined below are by no means sorted or capable of being sorted into wholly discrete categories, the boundaries of one sometimes blending into another.

Overall Benefit (Beneficence)

The argument is that public health is a good by definition, because most people benefit from it in one area or another. This is a net social gain type of argument.

The net gain argument is bolstered in modern economics by statistical models that seek to demonstrate population health benefits on an aggregated basis. These models often embed moral assumptions that are not always apparent under the guise of supposedly objective cost utility analyses. For example, the health of the elderly may be discounted as less valuable than the health of the young: the rights of those with "poor" health habits may be devalued in contrast to those who attend (and can afford to attend) health clubs and gyms and shop at high-end food stores (see, e.g., Brock, 2002; Gafni, 1991; Powers & Faden, 2006). And lurking in the shadows of cost utility analyses in the public health arena is the ever present specter of eugenics.

As Faden and Shebaya (2010) state,

> There is the risk that the findings emerging from these formal analyses will have determinative influence in policy circles. This risk is augmented by the increasing interest in attempting to empiricize moral considerations by measuring and aggregating the value preferences of the public about moral tradeoffs such as prioritizing by age or life-saving potential (Baker et al., 2008; Menzel et al., 1999; Nord, 1999). These aggregated preferences are then transformed into weights intended to incorporate moral values directly into the structure of the formal methodology, a move that is open to criticism on methodological as well as substantive grounds. (p. 17)

Applied to IWTs one can appreciate that green ideology could be "empiricized" to the point at which it trumps all other values in the development of wind energy policy.

Collective Efficiency

The argument is that in a complex society threatened by so many health risks from so many sources it is efficient for a central agency (public health) to oversee and regulate these risks because agencies organized according to specific issues could not hope to achieve the same level of proficiency.

While there is an intuitive appeal to this sort of argument, it fails to acknowledge the reality that public health concerns are often embedded in policies and practices that fall outside the sphere of public health agencies. IWTs are a leading example of this type of governmental dissonance. As noted above, the regulation of IWTs does not at present fall within an official public health remit in spite of the numerous and compelling claims advanced by various researchers in this issue.

Harm Prevention

The argument is that restriction or curtailment of the rights of a few can be justified only by prevention of harm to the many (Mill, 1869/1998).

This argument has been used in various public health and safety contexts but usually the contrast is between incursions on individual liberty (as in the case of compulsory seat belt or helmet use and no smoking in public places rules) and collective health benefits. In the case of IWTs, the contrast as noted already is between health benefits to the many versus health risks to a few, a situation to which the Harm Principle may not be best suited, although it must be said that advocates' claims for IWTs go beyond collective health benefits to embrace other putative social goods. These include increased freedom from reliance on nonrenewable energy sources. Insofar then as the contrast is between sacrificing the health of a few in the service of an anticipated bright energy future for the many, perhaps the Mills formulation is more useful. In this context, the prevention of harm to the many becomes a projected scenario in which the majority is "not harmed" by the perpetual threat that oil, gas, and even coal may run out or become inaccessible to us. Certainly, the trade-off is between a clear and evident loss to a few and the unknown, even vague probability of benefit to the many.

Paternalism

The argument is that government can interfere with the liberty or other rights of a few because it is ultimately in their best interests and certainly in the interests of the majority.

In the case of IWTs, the strong paternalistic case is made implicitly and sometimes explicitly that opponents are stupid, stubborn, or both because they do not know what is best for them in the long run. Their stupidity therefore disqualifies them from any further participation in the determination of their own fate.

A softer "libertarian" version of paternalism requires that until people are led to understand the benefits of the measures to which they are about to be unwillingly exposed they should not be subjected to them. Some argue that this is not paternalism at all but rather a form of participatory governance consistent with grassroots democracy. In any event, in this version people who did not accept that IWTs were likely to be a net benefit to them would not be obliged to consent to have them installed within a range accepted by the more prudential scientific community as likely to cause harm to their health.

Fairness

The argument is that in a democratic society we expect a relatively even social distribution of burdens when these are imposed and directed by government. Unequal distribution is unfair and therefore requires specific justification. In the case of IWTs, this justification might take the path of suggesting that all of us ultimately benefit from green energy in reduced pollution and eventually in freedom from reliance on nonrenewable fossil fuel sources. Consequently, harm to a few is justified by good for the many, which may even include the few who suffer in the short run but reap benefits in the end.

A particular problem arises in this context involving the disproportionate impact of certain public health measures on already disadvantaged groups. In the case of IWTs, this refers to those home and business owners who are economically disadvantaged to the extent that they do not have the option to sell and move from the location in which they are being harmed or expect to be harmed by the careless introduction of wind energy generators.

Again as Faden and Shebaya (2010) state,

> There is broad agreement that a commitment to improving the health of those who are systematically disadvantaged is as constitutive of public health as is the commitment to promote health generally (Institute of Medicine, Committee for the Study of the Future of Public Health, 1988; Nuffield Council on Bioethics, 2007; Powers & Faden, 2006, Thomas, Sage, Dillenberg, & Guillory, 2002). (p. 14)

Faden and Shebaya (2010) continue,

> When the burdens of a policy fall heavily on those who are already disadvantaged, the justificatory hurdle is particularly high. This concern is at the heart of many environmental justice controversies such as the locating of hazardous waste facilities and hazardous industries in low income communities and countries. (p. 16)

In other words, it is contradictory to the essence of public health ethics, at least insofar as it is grounded in fairness, to further disadvantage the already disadvantaged.

As we explore the further reaches of legitimacy in the next section of this article, fairness will be seen to take on an even more important role.

The Broader Canvas: Political Legitimacy, Social Justice, and IWTs

As noted earlier, public health ethics discourse as applied to IWTs is antecedent to a further-reaching discussion of political legitimacy. This connection is of vital importance in the case of IWTs because, as observed already, the regulation of IWTs does not fall within the public health remit but rather resides in other administrative bodies. Consequently, public health bodies have no direct control over the ways in which IWT installations are approved or sited. This dissociation of powers is in itself problematic and should be a matter of concern to all who govern in the name of the people. However, the issue of the public health impact of IWTs arises not only in the specific arena of institutional public health but also in the arena of political legitimacy generally.

Two fundamental questions of political legitimacy are the following: What gives government the right to govern in a democratic society in the first place? What gives it the ongoing right to coerce compliance with its laws and regulations?

These sound like simple if not simplistic questions but they have consistently eluded answers to which all can agree ever since people began to ask them.

Indeed, it is well to consider the context in which these questions were first asked in any really public and secular context, which was during the 17th century. Prior to that, natural law and divine right had been the source of the dominant accounts of political legitimacy and authority.

Early accounts of alternate sources of legitimacy concentrated on the nature of consent as the basis of political authority. Locke's treatise on the social contract is perhaps the best known of these accounts but there are many others that either elaborate on his thesis or challenge it (Peter, 2010). Essentially, however, Locke's account is based on not only "originating consent" (how government first got its mandate from the people) but on a form of ongoing majoritarianism. As Locke (1690/1990) wrote,

> Every man, by consenting with others to make one body politic under one government, puts himself under an obligation to every one of that society to submit to the determination of the majority, and to be concluded by it; or else this original compact, whereby he with others incorporates into one society, would signify nothing, and be no compact if he be left free and under no other ties than he was in before in the state of nature. (Locke, 1690/1990, p. 52f)

Modern descendants of earlier theories of consent now considered to be overly simplistic focus on notions of public reason and/or democratic approval drawing on the works of Kant and Rousseau, respectively (Peter, 2010).

One of the leading embodiments of these derived accounts is the seminal work of John Rawls (2001; see also Rawls, 1971), who grounds his theory of justice and legitimacy in fairness as a normative social practice.

This writer subscribes to Rawls's theory and declares his bias in this matter.

Fairness, as Rawls defines it, is to be not only a basis for everyday interactions among citizens but also the basis of interactions between government and citizens.

Fairness, as Rawls sees it, is the requirement to recognize and accommodate up to a standard of reasonableness the legitimate interests, claims, and rights of others.

Shain (2001) further articulates this requirement of fairness as it applies in domestic and institutional situations. Drawing on Trebilcock (1993), he identifies two impediments to the normative application of fairness as defined above: information failure and participation failure. Essentially, failures in these areas represent a failure of active consent, thus bringing full circle the links between fairness, legitimacy, and social justice.

The failure of information and participation are of particular relevance in the context of IWT installations where the alleged perfunctory adherence by government and proponents to regulated requirements for consultation with the public has attracted some harsh criticism.

Information and participation failure is abetted by any system of administrative law in which the principles of natural justice (e.g., let the other party be heard, the rule against bias, and the requirement of reasonableness) have become casualties. So much of what goes on under the auspices of administrative law is hidden from or ignored by the public to the point where the erosion of some of our most basic rights can go unremarked (Harlow, 2006).

So it is with IWTs, the story of which, in many jurisdictions, is representative of much that ails our system of administrative law. Anecdotal and deposition evidence from homeowners, community groups, and even municipalities in Canada and beyond frequently testify to the bankruptcy of the consultative process that should embody the principles of information sharing, transparency, and participation.[1]

Active consent to the rules and procedures that govern site location and installation of IWTs must be sought or obtained in a substantive way from those who are most likely to be affected by them, namely, residents in affected areas and the municipalities in which they live.

Fairness as an applied modern version of social contract theory calls for an active process in which all participants to a decision are engaged in ways that do not, without offer of compensation, advantage one party over another and in which there is an imperative to discover, acknowledge, and accommodate up to a standard of reasonableness one another's legitimate interests, claims, and rights.

In such a process, there are no preconceived "trump" values or considerations. For example, regulations under the Green Energy Act in Ontario cannot legitimately (according to a Rawlsian view) simply trump the claims and rights of subpopulations of citizens to the protection of their own and their families' health or enjoyment of their property based on some preconceived and unconfirmed notion of overall benefit to population health. However, that said, there are modern scholars who propose that there can be certain "preemptive" reasons that would allow governments to trump other considerations and interests if the authority behind the action were considered credible, rational, and legal enough for them to do so (see, e.g., Raz, 1986, 1995, 2006). The credibility of "preemptive" reasons, however, requires a virtually nonnormative Weberian account of legitimacy that is based on tradition, charisma, or some other kind of faith-based belief in the rightness of authority (Weber, 1918/1991; see also Weber, 1964). This is not considered to be mainstream thinking about the legitimacy of governmental action in Western democracies (Peter, 2010).

Various other critiques of consent as the basis of legitimacy see it as wishful thinking (e.g., Wellman, 1996) or as a delusion born of a desire to not acknowledge that many, now legitimate governments were born of violence (e.g., Hume, 1748/1965). Such arguments paved the way for the sorts of pragmatic, utilitarian justifications for public health measures that were scouted in the previous section.

Notwithstanding these objections to consent—in some form at least—as the basis of political authority and legitimacy, beliefs in its importance are probably the most current and widely held in our society today (Peter, 2010). We place a high value on the idea of consent in how we are governed even if in reality it is difficult to invest it with practical meaning. Effectively, consent is at the heart of how we create and honor contractual promises that extend beyond the realm of private transactions to that of state and civic governance. When we depart from the principle of consent, we feel obliged to give some account of how that can be justified, and eventually we return to the basic premise that it is desirable to place consent of the governed at the center of our communal life.

From the foregoing discussion and analysis, this writer proposes that Rawlsian fairness and its implied requirement of active consent emerge as the public health ethical principles most likely to serve the needs of a robust and legitimate democracy.

If that is taken as working assumption, what practical guidelines can be extrapolated from such principles to assist governments in the determination of criteria for approving IWT license applications?

In this regard, three emerging legal doctrines may be drawn on for assistance. These have roots in common law and in international law. They appear to be highly relevant to how we might usefully think about how IWT proposals can be fairly evaluated and judged. One doctrine—the Precautionary Principle—has been applied in an administrative law context in Canada already. The other two—the Neighbor Principle and the Least Impactful Means Test—remain to be fully articulated as such in an administrative law context but their emerging shape can be nonetheless discerned from recent cases.

These three doctrines are "before the fact" tools in that they are used to prevent harm from occurring in the first place.

A fourth doctrine—the Polluter Pay Principle—is an "after the fact" financial compensation tool that has long legal roots in all common law jurisdictions.

The Precautionary Principle

It was imported into Canadian law via the Supreme Court case of *Spraytech v. Hudson (Town)* [2001] 2 S.C.R. 241 from international law where it was originally approved by Canada in the Bergen Declaration of 1990. Subsequently, this doctrine has been embedded in several pieces of Canadian legislation including the Oceans Act, S.C. 1996, c. 31, Preamble (para. 6); Canadian Environmental Protection Act, 1999, S.C. 1999, c. 33, s. 2(1)(a); Endangered Species Act, S.N.S. 1998, c. 11, ss. 2(1)(h) and 11(1).

It means the following: When scientific evidence concerning the harm potential of a given industrial activity leaves room for doubt, that activity should not be undertaken. Proposed mitigating measures are not an adequate response, because if you do not know the nature or degree of risk you cannot prepare for its eventuation.

Some doubt surrounds the standard of care required by this principle. For example, how much harm could or should be reasonably foreseen if a risk eventuates? How big must the risk be to activate the principle? Currently, this principle is being tested in Ontario's legal and quasi-legal systems as it may be applied to IWT licensing. Such testing is likely to go on for some time. A recurrent issue appears to be the extent to which the Precautionary Principle that may be embedded in governing or parent statutes (such as Environmental Protection Acts) evaporates as delegated legislative vehicles such as regulations and administrative orders are created under its supposed authority.[2]

The Least Impactful Means Test

Evident from recent decisions of the Ontario Municipal Board, which is an administrative tribunal similar to many others in North America and the United Kingdom, this test means the following: State issuers of licenses should approve only those proposed methods of operation that will have the smallest social and environmental impact in pursuit of legitimate industrial objectives.

The Least Impactful Means Test is generically related to the Proportionality Test, which has currency in many countries including Canada. This test requires a form of ends-means analysis in which the requirement that the government provide justifications for statutes that infringe on protected rights is front and center (Beatty, 2004). In Canada, the Supreme Court case of *R. v. Oakes* [1986] 1 S.C.R. 103 is usually seen as the source of the proportionality test, which was stated as follows:

> First, the measures adopted must be carefully designed to achieve the objective in question. They must not be arbitrary, unfair or based on irrational considerations. In short, they must be rationally connected to the objective. Second, the means, even if rationally connected to the objective in this first sense, should impair "as little as possible" the right or freedom in question. Third, there must be a proportionality between the effects of the measures which are responsible for limiting the Charter right or freedom, and the objective which has been identified as of "sufficient importance."

As is apparent from the wording above, the test was developed to deal with infringements of the Canadian Charter of Rights and Freedoms by government actions such as law enforcement (as in the Oakes case) and law enactment (in other cases). Beatty (2004) shows convincingly, however, that in a number of countries, proportionality analysis is treated as a general principle of public law, applicable not only to constitutional law but also to administrative and even to international law questions.

However, Beatty is not alone in relating the proportionality test to the integrity of the rule of law. Harlow (2006) makes a similar connection in her consideration of the question whether or to what extent we can observe the emergence of a global administrative law with common principles and values. Central to such considerations is the question of when the State or its agencies can be held to be acting "ultra vires"—that is, beyond its legitimate powers and therefore unconstitutionally.

The marriage between the emerging jurisprudence of administrative tribunals in Ontario and the jurisprudence of the Supreme Court and the international community has not yet taken place. But the courtship is in progress and awaits only the brokerage and determination of creative lawyers to firm up the bond.

The Neighbor Principle

Also evident by deduction from recent Municipal Board decisions,[3] this is a common law legal doctrine that until recently applied only to claims of negligence in civil courts.

It means the following: basically, there is a legal duty of care to know enough about your neighbors to avoid doing predictable harm to their legitimate interests. A neighbor in this context is anyone who could be foreseeably affected by your acts or omissions. The standard of care is that of the reasonable person in the same situation.

However, the neighbor principle is now being referred to by implication in environmental cases where the expectation is raised that "reasonable" developers should know what social and environmental interests of their neighbors are foreseeably affected by their operations.

The relatively new concept of a "social impact zone" in municipal board jurisprudence (see examples of such decisions in Note 3) arguably requires developers to consider the foreseeable impact of their operations in certain defined areas. Ultimately, the Neighbor Principle takes its place within the framework of the Good Planning Test that pulls together all the expert information available to determine the extent to which proponents have discharged their duty to demonstrate no unacceptable or, in some cases, no negative impacts from their proposed operations.

This means that they should be aware of not only the commercial and business interests of neighbors but also of their reasonable social expectations of privacy, freedom from nuisance, and enjoyment of property. These are all "legitimate" interests.

It can be seen that all three aforementioned doctrines are allied to the Rawlsian concept of fairness as the recognition and reasonable accommodation of the legitimate interests claims and rights of others.

Indeed, it is this very concept of fairness that has the potential to unite the three doctrines into a coherent jurisprudence of social and environmental stewardship.

The Polluter Pay Principle

This well-established common law principle is evident from many Canadian cases including the Supreme Court case of *St. Lawrence Cement Inc. v. Barrette* [2008] SCC 64 and *Smith v. Inco* (2010) ONSC 3790 (CanLII). It is also enshrined in various forms of legislation.

It means that when an industrial operator is found to have caused loss to its neighbors it must compensate them for such loss regardless of whether there was negligence or not. This strict liability rule (a feature in many common law jurisdictions) has most recently been applied in a class action suit involving nickel contamination. The impact zone within which such losses will be considered varies from case to case.

Essentially, the polluter pay principle is a generic way of describing a class of private civil remedies that includes nuisance, trespass, and negligence. These are legal tools that are used in most cases after damage has been done except where injunctions and other interlocutory measures are used to stop harmful actions before they begin or while they are in progress. They really represent the failure of prevention.

Conclusion

A public health ethics analysis of how IWTs should be licensed and installed if the health of the few is to be balanced with, traded off or sacrificed for the health of the many, leads to the conclusion that the present methods of proposal evaluation need to be critically reviewed.

The only type of test that present methods would easily pass is "strong paternalism"—the argument that the State knows best. But this justification for public health measures enjoys little support in a free and democratic society.

With regard to the broader issue of governmental legitimacy and IWTs we are confronted with an even more profound problem. State actions that do not enjoy the active consent of the people—particularly of those whose health may be adversely affected by IWTs—are fundamentally suspect.

Administrative law systems that stray from the principles of natural justice held to underlie them are also suspect because such departures are in conflict with the Rule of Law.

Unfortunately, we do not find ourselves in this situation as a result of any one remediable action or default on the part of government but rather as a result of a gradual erosion of our collective capacity to hold government accountable.

IWT licensing procedures in whatever jurisdiction are a bellwether of the fate of democracy itself and therefore should be closely examined against the criteria suggested in this article, and in particular against the criterion of procedural fairness and active consent advocated by Rawls.

Several tools present themselves as proactive means of addressing perceived threats to procedural fairness and active consent: the Precautionary Principle, the Least Impactful Means Test (supported by the more general jurisprudence of the Proportionality Test), and the Neighbor Principle (drawn from the more specific requirements of the Social Impact Zone Test).

Converted into criteria for evaluation of IWT license applications, these principles and tests represent a formidable array of protections against arbitrary governmental action. That said, conversion into practical evaluative tools will require creative thinking and benign intent if we are to emerge with a more robust spine to our system of governance and administrative law.

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Notes

1. See also the Carmen Krogh article in this issue.
2. See, for example, the situation described in *Hannah v. Attorney General for Ontario*, 2011 ONSC 609.
3. Rockfort Quarry Hearing (2010) Ontario Municipal Board (Nov. 12th) PL000643, PL060448 (Campbell); Puslinch (Aikensville) Quarry Hearing (2010) Ontario Municipal Board (Jan. 19th) PL080489 (Jackson).

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Bio

Martin Shain S.J.D. is trained in law and social sciences. He is principal and founder of the Neighbour at Work Centre® and assistant professor at the Dalla Lana School of Public Health, Occupational and Environmental Health Division, University of Toronto.

APPENDIX 2

Acoustic Group Pty. Ltd., Consulting Acoustical and Vibration Engineers.

Review of Draft Wind Farm Guidelines 42.4963.R2.ZSC

14th March 2012

EXECUTIVE SUMMARY

In late 2011 The Acoustic Group performed a desk-top review of the acoustic documents comprising the acoustic assessment for the Flyers Creek Wind Farm and conducted preliminary sound monitoring at an existing operational wind farm (the Capital Wind Farm) which was approved in New South Wales on the basis of similar analyses, guidelines and reports to that provided for the Flyers Creek Wind Farm. The assessment found deficiencies and inadequate information in the acoustic assessment of the Flyers Creek proposal such that the true acoustic impact of the proposed wind farm had not been presented to the community.

In the intervening period a set of Draft Wind Farm Guidelines have been issued by the NSW Department of Planning and Infrastructure ("the Department") for public comment.

The Acoustic Group was requested by the Flyers Creek Wind Turbine Awareness Group to examine the Draft Wind Farm Guidelines with respect to acoustic issues. As there are no acoustic compliance reports for operational wind farms in NSW in the public domain, The Acoustic Group was also requested to conduct additional testing to assess the Draft Guidelines with respect to practical aspects of their application to operating wind farms.

The Draft Wind Farm Guidelines have identified that they closely follow the existing South Australian Guidelines in relation to the noise criteria. The problem for the broader community in comprehending the Guidelines is that from a noise perspective by definition, the Guidelines must be expressed in technical terms which are not readily understood by the community. The community therefore relies on the preparation by the Department of noise guidelines that set rigorous criteria and assessment procedures as well as a rigorous compliance regime. A reasonable person would expect that such Guidelines would be drawn from and based upon solid data and measurements. *Despite the fact that the Department has had the opportunity to scrutinize data and undertake scientific investigations of operating wind farms for the purpose of the Draft Guidelines, it has not done so.*

The Draft Wind Farm Guidelines set out measurement, assessment and compliance procedures which are likely to be unworkable in practice. This review highlights a number of outstanding issues in relation to noise impacts from wind farms that require the Draft Guidelines to be amended in order to safeguard the acoustic amenity of residents in areas where wind farms are proposed and where there has previously been no such noise source.

It is recommended that the proposed base criteria for wind farms be amended to 30 dB(A) when assessed under the worst case scenario. In particular, it is concluded:

1. There is no material or reference in the Guidelines supporting the use of 40 dB(A) as an acceptable amenity level in rural NSW. Examination of the Department's compliance review

of the Capital Wind Farm confirms Leq levels when turbines are shut down which are significantly lower than 40dB(A) and which undermine this standard as an acceptable amenity.

2. The Draft Wind Farm Guidelines ignore "Offensive Noise." In so doing, the Guidelines set criteria which are inconsistent with the EPA's Industrial Noise Policy. Examination of noise data from the Capital Wind Farm confirms that the current Draft Guidelines will permit noise significantly above background level i.e. offensive noise which is likely to interfere unreasonably with a person's health, comfort or repose.
3. The base limit for wind farms should be 30 dB(A) when assessed under the worst case scenario. Testing establishes that this limit would be consistent with EPA guidelines for the protection of acoustic amenity in rural areas.
4. The Guidelines are vague and inconsistent in relation to the assessment of and measurement during temperature inversions. This undermines the efficacy of the noise criteria.
5. The use of the A-weighting filter is not sufficient to account for the audibility and annoying characteristics of wind farm noise. This is demonstrated with data obtained from the Capital Wind Farm, Woodlawn Wind Farm and Cullerin Range wind Farm.
6. The guidelines do not specifically require full spectrum noise monitoring inside residential properties. Data obtained demonstrates that such monitoring is essential to reflect noise impact and specific noise characteristics.
7. The Guidelines require more detailed acoustic analysis at the proposal stage to identify the effects of different weather scenarios. These scenarios are typically required for industrial noise assessments and in their absence, proper compliance monitoring is impossible.
8. The measurement procedure in relation to specific noise characteristics describes measurements conducted over a 10 minute period. This does not permit identification of these characteristics which are associated with swish, modulation, discrete tones and low frequency noise. This is demonstrated with analysis of data from operating wind farms. Criteria in relation to amplitude modulation are uncertain.
9. Examination of data demonstrates that compliance monitoring can only be effective with the provision of permanent noise monitoring within the wind farm, recording noise levels, wind speed and direction at receiver locations and recording wind speed and direction at hub height. The Guidelines do not, but should, provide for such permanent noise monitoring supplemented with temporary remote monitoring in real time to deal with complaints.
10. The provision of permanent noise monitoring data together with real time presentation of the wind speed and direction at the hub, the power output and operational status of individual turbines must be provided in the public domain to permit independent compliance testing. There is no provision for this in the Draft Guidelines.
11. Compliance procedures are ineffective. The Guidelines do not provide a clear indication of what triggers non-compliance. The specified effects of non-compliance are vague. There are no provisions requiring a cessation of operations if the wind farm is not compliant.

Retrieved from:

http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=YLfMeRzXkhs%3D&tabid=205&mid=1081&language=en-US

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND	* * * * * * * *	**RESPONSE TO** **STAFF'S FIRST SET OF DATA REQUESTS TO INTERVENORS** **EL18-026**

Below, please find my response to Staff's
First Set of Data Requests to Intervenors. Thank you for allowing me the extension to submit my response by August 24, 2018, at 5:00 pm.

1-1) Provide copies to Staff of all data requests served on Applicant at the time of service.
I will provide this information.

1-2) Provide copies to Staff of all of your answers to data requests from Applicant at the time they are served on Applicant.
I will provide this information.

1-3) Refer to SDCL 49-41B-22. Please specify particular aspect/s of the applicant's burden that the individuals granted party status intend to personally testify on.
I am in the process of reviewing the Application to find if it is sufficient to provide for the conditions set forth SDCL 49-41B-22. I have not decided if I will testify or not.

1-4) Refer to SDCL 49-41B-25. Identify any "terms, conditions, or modifications of the construction, operation, or maintenance" that the Intervenors would recommend the Commission order. Please provide support and explanation for any recommendations.

To be clear, I recommend that the Commission deny this application. I recommend this from my experience of the Beethoven Wind Farm from permitting, construction, to the operation of it, to date.

If the Commission will not deny the application, I recommend the condition of a 4-mile setback. My support is the fact that I live 3 miles from six Beethoven Wind Farm Industrial Wind Turbines and the height of 586 foot turbines as the Applicant has chosen is unprecedented and I believe will negatively impact my husband and myself without the 4 mile setback.

I request the ALDS which eliminates the alarming red blinking lights at night. If the FAA does not approve them, I recommend the application be denied.

The red blinking lights are meant to alarm. The red blinking lights on the Beethoven Wind Farm are a nuisance. To have an additional 57 turbines, many with the alarming red blinking lights will be result in a much bigger nuisance. The Applicant should be prevented from creating a nuisance.

I request a **Bat Detection** and Shutdown **System be installed on all Industrial Wind Turbines in this project. Bat fatalities negatively affect agriculture and the environment.**

I request a decommissioning bond, paid for up front. Once the Industrial Wind Turbines are up, they are up. Whether or not the proposed Industrial Wind Farm will be lucrative enough to produce the income to provide for a bond in ten years is not and cannot be proven.

I request a liaison person to monitor the project as it is being built to insure compliance and an avenue for those in the footprint to voice concerns and complaints. A project of this size must have a liaison.

I request a liaison person to monitor the project from the commencing of operation through the decommissioning. I have not been able to reach anyone to assist me when I have had concerns with the existing Beethoven Wind Farm.

I request there be no shadow flicker on non-participating residences, as shadow flicker presents a nuisance and the Applicant should be prevented from creating a nuisance.

I request a Guarantee of Property Value to be funded and developed by the Applicant, subject to approval of the Property Owner to protect residents in the footprint and buffer zone from financial loss should the residence become unlivable and / or unmarketable. The Applicants project will have serious financial implications on many of the residents in the footprint and the buffer zone.

1-5) Is there a specific objection (example health, blinking lights, sound) you have with respect to the Project? Please briefly explain.

The nuisance of red blinking lights as mentioned above in section 1-4. If the FAA will not approve the use of the ALDS the application should be denied.

Most concerning is sound, both audible and infrasound. There are many complaints about both audible and inaudible noise from Industrial Wind Turbines, they are well documented. The result of negative health effects to some residents from both audible and inaudible noise is also well documented.

Health, again the size of the Industrial Wind Turbines the Applicant has chosen is unprecedented. The area and range they will impact is unknown and will likely cause the loss of enjoyment of property, loss of use of property, loss of the residence to be inhabitable, and the marketability of property will be greatly diminished.

What, if anything, do you feel could be done to remedy that issue?

Deny the Application.

If the Commissioners will not deny the application, the Commission must then approve the Application with conditions that will truly protect the health, safety, and welfare of all of the residents living in and near the footprint.

Sound should not exceed 35 decibels for non-participating residences.

Setbacks should be 4-miles from a non-participating residence.

An ALDS must be installed. If the FAA does not approve an ALDS the application should be denied.

1-6) Please list with specificity the witnesses the Intervenors intend to call. Please include name, address, phone number, credentials and area of expertise.
I am still reviewing the Application and have not decided if I will call witnesses.

1-7) Do the you intend to take depositions? If so, of whom? **Not at this time.**

Dated this 24th day of August, 2018

Karen Jenkins
28912 410th Ave
Tripp, SD 57376
605-680-5646
jenkinskd55@gmail.com

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF SOUTH DAKOTA**

IN THE MATTER OF THE APPLICATION BY PREVAILING WIND PARK, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN BON HOMME COUNTY, CHARLES MIX COUNTY AND HUTCHINSON COUNTY, SOUTH DAKOTA, FOR THE PREVAILING WIND	* * * * * * * *	**STAFF'S FIRST SET OF DATA REQUESTS TO INTERVENORS** **EL18-026**

Below, please find Staff's First Set of Data Requests to Intervenors. Please submit responses by August 22, 2018, at 5:00 pm, or promptly contact Staff to discuss an alternative arrangement.

1-1) Provide copies to Staff of all data requests served on Applicant at the time of service.
None served at this time.

1-2) Provide copies to Staff of all of your answers to data requests from Applicant at the time they are served on Applicant.
None received at this time.

1-3) Refer to SDCL 49-41B-22. Please specify particular aspect/s of the applicant's burden that the individuals granted party status intend to personally testify on.
1) Inaccuracies, errors, and omissions in the applicant's application and supplemental information may cause injury to the environment leading to the economic detriment of some inhabitants and businesses within and near the project as well as distressing other activities.
2) The applicant fails to substantially prove that placement of turbines twice as powerful as existing turbines and at distances even closer than existing turbines will not substantially affect the health, safety or welfare of either participating or non-participating inhabitants. Unless health, safety, and welfare have been quantitatively measured prior to construction the amount of substantial impairment can not be measured after. Personal health and well-being will be particularly emphasized.
3) There will likely be no future "orderly development" at all in the footprint of the facility if constructed as proposed.

1-4) Refer to SDCL 49-41B-25. Identify any "terms, conditions, or modifications of the construction, operation, or maintenance" that the Intervenors would recommend the Commission order. Please provide support and explanation for any recommendations.
The "terms, conditions or modifications" that would ameliorate nuisance, health, and negative financial concerns raised by the facility would be to simply deny the permit.
Should the permit be approved, full frequency spectrum analysis should be performed, including using the C-weighted scale (Broner and Leventhall 1983) not just modeling of projected dB(A) levels. The complete sound output needs to be accounted for not just the audible portion as with the dB(A) weighted scale. Dr. Alec Salt and colleagues,

Washington University School of Medicine, St. Louis have explained the effects of extremely low frequency sound on the inner ear leading to the distress of sleep disruption, sleep deprivation and subsequent adverse health effects. Larger and more powerful turbines produce an even larger proportion of low frequency noise than earlier smaller models. This needs to be accounted for by someone.

If appropriate sound power level studies are not implemented and standards set and enforced, an alternate condition for safety, health, and welfare would be setbacks of 2 miles from non-participating residences, businesses, churches, cemeteries, and schools with waivers for those so inclined and 1500 foot setbacks from property and right of way lines. All horizontal setback measurements need to be made to the tip of the blade when horizontal not to the center of the tower.

Aircraft Detection Lighting Systems should be installed. The air ambulances from the Sioux Falls hospitals make multiple trips to the Wagner hospitals every week at all hours of the day and night through the proposed facility area.

Shadow flicker should be eliminated at non-participating residences and business and should be reduced to 8 hours annually actual following the German model at participating residences so as not to imprison people their homes behind shuttered windows unable to use their own property.

Decommissioning monies should be made available in whole upfront and reevaluated every 2 years to account for inflation and other increasing costs. Decommissioning should include complete removal of all installed components not just visible portions.

1-5) Is there a specific objection (example health, blinking lights, sound) you have with respect to the Project? Please briefly explain.

a. What, if anything, do you feel could be done to remedy that issue?

Concerning sight, sound, health, and safety issues:

If constructed as proposed our horizon will be in constant motion when the wind blows except for about 60 degrees to the north. As someone susceptible to motion sickness and having suffered vertigo episodes within the last few months, this may well be an unbearable situation. Infrasound and low frequency noise from existing turbines may contribute to these issues as per Navy nauseogenic studies but I can not imagine that having larger turbines on all sides could possibly help.

Existing turbine noise is routinely audible at our residence at 1.25 miles distant. Note that applicant's sound study indicates that in 2 of 3 measurements at measuring points 1 and 2 there is audible sound from existing turbines at distances of approximately 2 miles. Again, being completely surrounded by larger turbines will not help the situation.

Both audible sound and inaudible low frequency noise are known to contribute to sleep disruption and sleep deprivation. The distress of sleep deprivation over time is known to cause physiological disruptions of several body systems. We already experience sleep problems. Being surrounded by more and larger turbines can not possibly help.

Possible remedies for these issues could include but are not limited to:

1) Not approving the permit.

2) Requiring 2 mile setbacks from habitable residences, businesses, churches, cemeteries, etc. with waivers if desired by participating landowners so as to protect by

distance from sound, inaudible noise, and sight disruption. All property and right of way line setbacks should be at least 1500 feet for safety from blade fragmentation and ice throw. For risk assessment it should be presumed that a person is always present at the property or right of way line.

3) Requiring 2 kilometer setbacks (as many European countries and Australian states have previously required 1000 meters for much smaller turbines as per summary by K. M. B. Haugen, Minnesota Department of Commerce) but from non-participating landowners property lines, along with noise limits of 25-40 dB(A) (again foreign country guidelines adjusted for turbine size per Haugen summary) at non-participating landowner property lines with lower values for measured quiet areas or 5 dB(A) or less above measured preconstruction ambient background noise levels with 5-15 dB penalties for tonality, impulsiveness, and modulation (Haugen summary) at the property line of non-participants so as not to imprison people in their homes unable to use or enjoy their entire property.

4) Further remedies to reduce audible sound and low frequency noise could include shutting down the entire facility from 7:00 pm to 7:00 am so that all inhabitants could sleep peacefully, shutting down all turbines within 2 miles of non-participating residences or 2 kilometers of non-participating owner property lines from 7:00 pm to 7:00 am, using Noise Reducing Operations (NRO) on all turbines from 7:00 pm to 7:00 am, or using NRO on turbines within 2 miles of non-participating residences or 2 kilometers of non-participating landowners property lines 24 hours a day.

Setbacks from property lines are stressed because our practice of animal husbandry requires working afoot on the majority of our property on a daily basis. Measurements to the residence are useless except for sleeping hours. No one should be denied the use of the entirety of their property.

1-6) Please list with specificity the witnesses the Intervenors intend to call. Please include name, address, phone number, credentials and area of expertise.

Potential witness other than self are unkown at this time.

1-7) Do the you intend to take depositions? If so, of whom?

Unknown at this time but doubtful.

21 August 2018

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Dated this 8th day of August 2018.

Kristen Edwards

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