

Industrial wind turbines and adverse health effects

Roy D. Jeffery, MD,
CCFP, FCFP
Manitoulin Island, Ont.

Carmen M.E. Krogh,
BScPharm

Brett Horner, BA,
CMA
Killaloe, Ont.

Correspondence to:
Roy Jeffery;
jeffery_07@sympatico.ca

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Introduction: Some people living in the environs of industrial wind turbines (IWTs) report experiencing adverse health and socioeconomic effects. This review considers the hypothesis that annoyance from audible IWTs is the cause of these adverse health effects.

Methods: We searched PubMed and Google Scholar for articles published since 2000 that included the terms “wind turbine health,” “wind turbine infrasound,” “wind turbine annoyance,” “noise annoyance” or “low frequency noise” in the title or abstract.

Results: Industrial wind turbines produce sound that is perceived to be more annoying than other sources of sound. Reported effects from exposure to IWTs are consistent with well-known stress effects from persistent unwanted sound.

Conclusion: If placed too close to residents, IWTs can negatively affect the physical, mental and social well-being of people. There is sufficient evidence to support the conclusion that noise from audible IWTs is a potential cause of health effects. Inaudible low-frequency noise and infrasound from IWTs cannot be ruled out as plausible causes of health effects.

Introduction : Des gens qui habitent à proximité des éoliennes industrielles affirment subir des effets préjudiciables pour leur santé et leur situation socio-économique. La présente analyse étudie l’hypothèse selon laquelle le désagrément causé par le bruit des éoliennes serait à l’origine de ces effets néfastes pour la santé.

Méthodes : Nous avons cherché dans PubMed et Google Scholar des articles publiés depuis 2000 et contenant les expressions « wind turbine health », « wind turbine infrasound », « wind turbine annoyance », « noise annoyance » ou « low frequency noise » dans le titre ou le résumé.

Résultats : Les éoliennes industrielles produisent un son qui est perçu comme étant plus désagréable que d’autres sources de bruit. Les effets signalés de l’exposition aux éoliennes industrielles correspondent à des effets de stress bien connus causés par des sons persistants non voulus.

Conclusion : Si elles sont situées trop près des habitations, les éoliennes industrielles peuvent avoir des effets préjudiciables pour le bien-être physique, mental et social des gens. Il existe suffisamment de preuves pour conclure que le bruit audible des éoliennes industrielles est une cause possible d’effets sur la santé. En outre, on ne peut écarter comme cause plausible d’effets sur la santé les sons de basse fréquence et les infrasons produits par ces éoliennes.

INTRODUCTION

Some people living in the environs of wind energy infrastructure experience negative health effects. Reported effects include annoyance, sleep disturbance, stress-related health impacts and re-

duced quality of life.¹⁻¹² In some cases, Canadian families have effectively abandoned their homes, been billeted by wind energy developers or negotiated financial agreements with developers.¹³

A 2009 case series by Pierpont⁶ included Canadian participants and

documented symptoms reported by people exposed to industrial wind turbines (IWTs). Documented effects included 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 called the symptoms “wind turbine syndrome” and proposed the cause to be low-frequency noise (LFN) from IWTs or vibration stimulation of receptors of the human balance system.⁶

The American Wind Energy Association and Canadian Wind Energy Association sponsored a literature review to consider the existing literature on wind turbine noise and health.¹⁴ Colby and colleagues¹⁴ determined that “‘wind turbine syndrome’ symptoms are not new and have been published previously in the context of ‘annoyance’ and are the ‘well-known stress effects of exposure to noise’”

In this review, we consider the hypothesis of Colby and colleagues that the health effects from IWTs are the result of annoyance from the noise of audible IWTs.¹⁴ We also discuss emerging knowledge on the effects of inaudible LFN and infrasound.

METHODS

We searched PubMed and Google Scholar for articles published since 2000 that included the terms “wind turbine health,” “wind turbine infrasound,” “wind turbine annoyance,” “noise annoyance” or “low frequency noise” in the title or abstract.

We also considered additional documents received following author correspondence. Additional documents included, but were not limited to, government documents obtained by freedom-of-information requests and literature reviews.

RESULTS

Definitions: noise and health

The World Health Organization (WHO) defines noise as “unwanted sound.”¹⁵ Noise of a moderate level acts via an indirect pathway and can have health outcomes similar to those caused by high noise exposures on the direct pathway.¹⁶ The main health risks of noise, identified by WHO, include the following: pain and hearing fatigue, hearing impairment, tinnitus, annoyance, interferences with social behaviour, interference with speech commu-

nication, sleep disturbance, cardiovascular effects, hormonal responses, and reduced performance at work and school.¹⁷

Canada supports the definition of health established in the 1948 WHO constitution: “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.”¹⁸ Michaud and colleagues state that “[u]nder this broad definition, noise-induced annoyance is an adverse health effect.”¹⁹

In a document about the process of environmental assessments, Health Canada states that it “considers the following noise-induced endpoints as health effects: noise-induced hearing loss, sleep disturbance, interference with speech comprehension, complaints, and change in percent highly annoyed (%HA).”²⁰

Effects of noise-induced annoyance

In a report on the health effects of wind turbines, the Minnesota Department of Health stated that “[t]he most common complaint in various studies of wind turbine effects on people is annoyance or an impact on quality of life.”²¹

Annoyance has been defined as “... a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them”¹⁵ A causal chain exists between strong annoyance and increased morbidity,²² and chronically strong annoyance must be classified as a serious human health risk.²³

Symptoms associated with annoyance include stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, anxiety, heart ailments and palpitation.^{24–26} In western European countries, noise-induced sleep disturbance and annoyance are estimated to account for 903 000 and 587 000 disability-adjusted life years, respectively.²⁷

Industrial wind turbines can be harmful to health

Literature reviews have commented on the health effects of IWTs. Systematic audits of reviews reveal that some works contain errors of omission or commission.²⁸ One recurring error of omission is the failure to disclose that IWT noise acting via the indirect pathway can cause health effects.

A 2011 Ontario Environmental Review Tribunal considered evidence and testimony under oath and found that IWTs can be harmful to health if they are placed too close to residents.²⁹ The tribunal decision also found that

“serious harm to human health” includes ... indirect impacts (e.g., a person being exposed to noise and then exhibiting stress and developing other related symptoms). This approach is consistent with both the WHO definition of health and Canadian jurisprudence on the topic.²⁹

Plausible causes of IWT-related health effects

Industrial wind turbines and related infrastructure can have a negative impact on living environments. Noise, visual impacts, stray voltage and socio-economic impacts related to IWTs are identified as plausible causes of adverse effects.

Electromagnetic waves in the form of poor power quality and ground current can adversely affect people who are electrically hypersensitive. Poor power quality and ground current have been documented at homes in proximity to Ontario IWTs.³⁰

The National Research Council reports that

... to the extent that wind-energy projects create negative impacts on human health and well-being, the impacts are experienced mainly by people living near wind turbines who are affected by noise and shadow flicker.³¹

The blades of IWTs produce unavoidable shadow flicker bright enough to pass through closed eyelids, and moving shadows cast by the blades on windows can affect illumination inside buildings.³² The Danish Energy Agency classifies shadow flicker from IWTs experienced by residents as a “nuisance.”³³

People exposed to shadow flicker from IWTs report negative effects to their health and well-being.⁷ Currently, most jurisdictions in Canada do not have regulations that prevent negative effects from visual burdens caused by IWTs.

Noise from IWTs is more annoying than other noises

The Canadian Wind Energy Association suggests that modern wind turbines are not noisy.³⁴ European peer-reviewed studies consistently document that IWTs produce sound that is perceived to be more annoying than transportation or industrial noise at comparable sound pressure levels.^{1,5}

In a 2006 report, the Académie nationale de médecine working group noted that IWT noise was the most frequent complaint.³⁵ The report described IWT noise as piercing, preoccupying and continually surprising because it is irregular in intensity, which distracts attention or disturbs rest. Industrial wind turbines have been blamed for other problems experienced by people living nearby, including subjective (headaches, fatigue, temporary feelings of dizziness

and nausea), and objective (vomiting, insomnia and palpitations) manifestations.³⁵

Health effects expected in rural Canada

Industrial wind turbines are sited in proximity to Canadian homes to enable access to transmission infrastructure.³⁶ Internal correspondence from the Ontario Ministry of the Environment, obtained through a freedom-of-information request, states, “It appears compliance with the minimum setbacks and the noise study approach currently being used to approve the siting of WTGs [wind turbine generators] will result or likely result in adverse effects ...”³⁷

A report commissioned by the Ontario Ministry of the Environment concluded that the sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, was

... expected to result in a non-trivial percentage of persons being highly annoyed ... research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons.³⁸

Noise annoyance in rural Canada is extremely low.^{39,40} Canadian communities with populations of less than 5000 report that about 70% are “not at all annoyed” by noise outside their home.¹⁹

Health Canada’s examination of the scientific literature on noise from IWTs determined the health effect “conclusively demonstrated” from exposure to wind turbine noise is an increase of self-reported general annoyance and complaints (i.e., headaches, nausea, tinnitus and vertigo).⁴¹ Members of Health Canada’s Consumer and Clinical Radiation Protection Bureau propose a sound limit of 45 dBA for IWTs and predict an increase in the percentage of Canadians highly annoyed by noise from IWTs.⁴²⁻⁴⁴

A noise immission level of 45 dBA from IWTs can be expected to result in “... less than 14% of the exposed population to be highly annoyed indoors by wind turbines and less than 29% to be highly annoyed outdoors.”⁴⁵

There is a greater expectation for, and value placed on, “peace and quiet” in quiet rural settings.^{44,46} Such settings in Ontario can have ambient sound levels below 30 dBA.³⁷ Annoyance from IWT noise starts at dBA sound pressure levels in the low 30s and rises sharply at 35 dBA.^{1,3,5} Research suggests that IWT noise limits should be set at 32 dBA outside residences.⁹ A 2010 memorandum of the Ontario Ministry of the Environment recommended

that IWT "... setback distances should be calculated using a sound level limit of 30 to 32 dBA at the receptor"³⁷ Ontario guidelines for IWT noise currently permit up to 51 dBA.⁴⁷

A health survey of people exposed to IWTs in Ontario reported altered quality of life, sleep disturbance, excessive tiredness, headaches, stress and distress.⁷ Predicted probability of health effects diminished with increased distance between the IWT and the participant's property.⁷ Nissenbaum and colleagues¹² also documented a reduction of effects with increased distances of IWTs from residences. These findings are consistent with the physics of sound decay through absorption by the ground and atmosphere.

Negative attitudes toward IWTs have been suggested as a cause of annoyance complaints.^{14,48} However, researchers have found that IWTs were initially welcomed into the communities for their perceived environmental⁸ or economic¹² benefits. As Krogh states, "[t]he reported adverse impacts were unexpected."¹³

Characteristics of IWT noise

The sound of IWTs is very easily perceived⁴⁹ and is difficult to mask.^{1,5} The characteristics of IWT noise that are identified as plausible causes for reported health effects include amplitude modulation,⁵⁰ audible low-frequency noise (LFN),²¹ infrasound,⁵¹ tonal noise, impulse noise and night-time noise.⁵

Amplitude modulation and impulse noise

Modern IWTs routinely produce audible amplitude modulation. Leventhall⁵⁰ reports that "[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." Pedersen and van den Berg⁵² state that "[f]rom various studies it follows that this modulation is equivalent in annoyance to the un-modulated sound at an approximately 5 dB higher level." Ontario noise guidelines require a 5 dBA adjustment for industrial noise that has amplitude modulation⁵⁵ but not for IWTs.⁴⁷ Industrial wind turbines also produce impulsive sound, which can be unexpected and disturbing to residents.^{9,54}

24 Audible LFN

Modern IWTs routinely produce audible LFN.³⁸ As IWTs have increased in size, so has the LFN

part of the sound spectrum. For modern IWTs, it is

... beyond any doubt that the low-frequency part of the spectrum plays an important role in the noise It must be anticipated that the problems with low-frequency noise will increase with even larger turbines.⁵⁵

Annoyance from audible LFN is acknowledged to be more severe in general.¹⁵ Low-frequency noise does not need to be considered loud for it to cause annoyance and irritation.²⁵ It causes immense suffering to those who are sensitive to it,²⁴ and chronic psychophysiological damage may result from long-term exposure to low-level LFN.⁵⁶

Infrasound and inaudible LFN

Industrial wind turbines also produce infrasound and/or inaudible LFN. There is debate about the impact from these low frequencies of noise.³⁸ It has been suggested that these low frequencies are not sufficient to result in negative effects.^{14,48,50} However, Farboud and colleagues⁵⁷ state that "... there is an increasing body of evidence suggesting that infrasound and low frequency noise have physiological effects on the ear." Salt and Kaltenbach⁵⁸ report, "[b]ased 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."

In a 1990 NASA technical paper, Hubbard and Sheppard⁵⁹ report that

[p]eople who are exposed to wind turbine noise inside buildings experience a much different acoustic environment than do those outside. ... They may actually be more disturbed by the noise inside their homes than they would be outside. ... One of the common ways that a person might sense the noise-induced excitation of a house is through structural vibrations. This mode of observation is particularly significant at low frequencies, below the threshold of normal hearing.⁵⁹

Low-frequency noise produced by some IWT projects in Ontario has been found to be inaudible outside the home but audible inside and "... quite annoying to the occupants."³⁷

Low-frequency noise from IWTs has resulted in reported annoyance, sleep deprivation and uninhabitable living conditions.³⁷ To escape the noise, some Ontarians report sleeping in vehicles, tents, trailers, basements lined with mattresses, garages, and at the homes of relatives or friends.¹⁵ Ontario does not have "... measurement procedures or criteria for addressing indoor noise intrusions due to wind turbines"³⁸

In 2012, a board of health resolution concerning an IWT project in Brown County, Wisconsin, requested

... temporary emergency financial relocation assistance from the State of Wisconsin for those Brown County families that are suffering adverse health effects and undue hardships caused by the irresponsible placement of industrial wind turbines around their homes and property.⁶⁰

A 2012 cooperative measurement survey and analysis of LFN and infrasound at the location concluded,

[t]he four investigating firms are of the opinion that enough evidence and hypotheses have been given herein to classify LFN and infrasound as a serious issue, possibly affecting the future of the industry. It should be addressed beyond the present practice of showing that wind turbine levels are magnitudes below the threshold of hearing at low frequencies.⁶¹

In 2013, research funded by the Ontario Ministry of the Environment indicated a statistically significant relation between residents' distance from the turbine and the symptoms of disturbed sleep, vertigo and tinnitus, and recommended that future research focus on the effects of wind turbine noise on sleep disturbance and symptoms of inner ear problems.⁶²

CONCLUSION

Health is one of the fundamental rights of every human being. Some people exposed to IWTs experience negative effects to their physical, mental and social well-being. There is sufficient evidence to support the hypothesis of Colby and colleagues¹⁴ that documented symptoms can result from annoyance to audible IWTs. Amplitude modulation of IWTs, audible LFN, and tonal, impulse and nighttime noise can contribute to annoyance and other effects on health. In addition, there is emerging evidence that suggests inaudible LFN or infrasound from IWTs may result in negative health effects.

Further research is required to clarify the exact role that sound characteristics, visual impacts, stray voltage and socioeconomic impacts of IWTs may have on human health. As more IWTs are installed, rural physicians are likely to be presented with increasing numbers of patients who are adversely affected. Based on current knowledge, we expect that, at typical setback distances and sound pressure levels of IWTs in Ontario, a non-trivial percentage of exposed people will be adversely affected. "Trade-offs" of health for perceived benefit in alternate forms of energy can be prevented if setback distances and noise limits are developed using established noise management

techniques. In addition to providing care for affected patients, rural physicians have a responsibility to advance understanding and to help inform IWT regulations that will protect the physical, mental and social well-being of patients.

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