

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

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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 psycho-physiological 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 persecond (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 non-reviewed 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 setback 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 nighttime 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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Bios

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