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Wind turbine noise: What has the Science Told Us?

Loren D. Knopper Intrinsik Environmental Sciences, 6605 Hurontario Street, Mississauga, Ontario, Canada, L5T 0A3. E-mail: LKnopper@intrinsik.com

Melissa L. Whitfield Aslund Intrinsik Environmental Sciences, 6605 Hurontario Street, Mississauga, Ontario, Canada, L5T 0A3. E-mail: MAslund@intrinsik.com

Lindsay C. McCallum Intrinsik Environmental Sciences, 6605 Hurontario Street, Mississauga, Ontario, Canada, L5T 0A3. E-mail: LMccallum@intrinsik.com

Christopher A. Ollson Intrinsik Environmental Sciences, 6605 Hurontario Street, Mississauga, Ontario, Canada, L5T 0A3. E-mail: COllson@intrinsik.com

Summary

Public attitude is generally overwhelmingly in favor of wind energy, yet this support does not always translate into unanimous local acceptance of projects. Opposition groups point to a number of issues concerning wind turbines, with human health one of the most common. While some argue that reported health effects are related to wind turbine noise (i.e., audible noise, low frequency noise and infrasound) others suggest that effects are more likely attributable to individual stress and personalities. Many scientific studies have been conducted world-wide to examine the relationship between wind turbines and possible human health effects (now close to 50). Based on a review of the science a number of health and medical agencies (as well as findings from legal proceedings) suggest that when sited properly, wind turbines are not causally related to adverse effects. Noise from wind turbines can be annoying to some and associated with some reported health effects (e.g., sleep disturbance), especially at sound pressure levels greater than 40 dB(A). Because environmental noise above certain levels is a recognized factor in a number of human health issues, many jurisdictions where wind turbines are being constructed have established noise restrictions and/or minimum setback distances in order to mitigate potential noise-based health effects.

1. Introduction

Wind power has been harnessed as a source of power around the world for decades and reliance on this form of energy is increasing. In 1996 for example, the global cumulative installed wind power capacity was 6,100 MW; in 2011, that value had grown to 237,669 MW (GWEC, 2012). While public attitude is generally overwhelmingly in favor of wind energy, this support does not always translate into local acceptance of projects by all involved (Upham et al. 2009). Opposition groups point to a number of issues concerning wind turbines, and their possible effects on human health is one of the most commonly discussed. Indeed, a small proportion of people that live near wind turbines have reported adverse health effects such as, but not limited to, annoyance, ringing in ears, headaches, lack of concentration, vertigo and sleep disruption, that they attribute to the wind turbines. This collection of effects has received the colloquial name "Wind Turbine Syndrome", a term coined by Dr. Nina Pierpont in her book "Wind Turbine Syndrome: A Report on a Natural Experiment" (Pierpont, 2009).

The reason for the self-reported health effects is highly debated and information fuelling this debate is found primarily in two sources: scientific peer-reviewed studies published in scientific journals and the popular literature and internet. Some argue that the reported health effects are related to two primary issues:

- Wind turbine noise (i.e., levels of audible noise, low frequency noise and infrasound); and
- Wind turbine operational effects (i.e., electromagnetic fields [EMF] frequencies and stray voltage from transmission lines and shadow flicker from rotor blades).

Others suggest that the science conducted points towards reported effects being more likely attributable to a number of environmental stressors that result in an annoyed/stressed state in a segment of the population. In other words, it appears that it is the change in the environment that is associated with reported health effects and not turbine-specific variables like noise. In this conference presentation we focus on what the science tells about wind turbines and human health, with a focus on noise and other possible non-turbine specific variables.

2. Experimental design

Combinations of key words (i.e., annoyance, noise, environmental change, sleep disturbance, epilepsy, stress, health effect(s), wind farm(s), infrasound, wind turbines(s), low frequency noise, EMF, wind turbine syndrome, neighborhood change) were entered into PubMed, the Thomson Reuters Web of Knowledge^{SM} and the internet search

engine Google. The review was conducted in the spirit of the evaluation process outlined in the Cochrane Handbook for Systematic Reviews of Interventions.

Sources of information other than peer-reviewed scientific literature and government agency publications (e.g., websites, opinion pieces, conference proceedings, unpublished documents) have purposely been excluded in this report because they are often unreliable, used as a platform for advocates, and provide information that is typically anecdotal in nature or not traceable to scientific sources. As such they often serve to spread misconceptions about the potential impacts of wind energy on human health making it difficult for the general public (and scientists) to ascertain which claims can be substantiated by scientific evidence and which cannot.

3. Results

3.1 Weight of Evidence

As of early 2011, only 13 articles had been published in the scientific literature whose focus was the association between potential health effects and wind turbine noise (see review in Knopper and Ollson, 2011). As of May 2013 there were closer to 50 (see reference section). Although hundreds of articles were found during the search, comparatively few were related to the association between potential health effects and wind turbines. For example, numerous articles have been published about infrasound, but comparatively few have been published about infrasound and wind turbines.

While some argue that reported health effects are related to wind turbine noise, be it audible or inaudible (e.g., Krough et al., 2011; McMurtry, 2011; Shepherd et al., 2011, Salt and Kaltenbach, 2011; Nissenbaum et al., 2012) others suggest reported effects are more likely attributed to a number of environmental stressors that result in an annoyed/stressed state in a small segment of the population. For example, in August 2011 authors of a number of popular literature studies published their findings in a special edition of the Bulletin of Science, Technology & Society (BSTS; Volume 31, Issue 4) devoted entirely to wind farms and potential health effects. The publication of these articles in BSTS has been touted by wind turbine opposition groups as evidence of the relationship between living in proximity to wind turbines and adverse health effects. Recent articles by Shepherd et al. (2011) and Nissenbaum et al. (2012) have looked at the relationship between wind turbines, health related quality of life and sleep disturbance (but see peer-reviewed critical review by Ollson et al. (2013) of Nissenbaum et al. (2012)). In terms of environmental stressors that result in an annoyed/stressed state in a segment of the population, the role of stress due to unwanted change, visual cue and attitude, poor coping, negative oriented personality and expectations related to media reporting have all been related to reported effects (e.g., Pedersen and Persson

Waye, 2004; Janssen et al., 2011; Bakker et al., 2012; Crichton et al., 2013; Deignan et al., 2013; Taylor et al., 2013).

Based on the findings and scientific merit of these studies, our opinion is that the weight of evidence suggests that when sited properly, wind turbines are not related to adverse health effects. This opinion is supported by findings of (and has also been made) a number of government health and medical agencies, including the National Health and Medical Research Council in Australia (2010), the Chief Medical Officer of Health in Ontario (2010), the Massachusetts Department of Environmental Protection and Public Health (2012), the Oregon Health Authority (2013) and the South Australia Environmental Protection Agency (2013). To illustrate the point:

- The National Health and Medical Research Council in Australia (2010) stated: *"There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines."*
- In 2010 Ontario's Chief Medical Officer of Health (CMOH) stated: *"The review concludes 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."*
- More recently, the MassDEP and MDPH (2012) concluded that best practices (i.e., noise and distance setbacks) protective of public health should be implemented in areas where wind energy is generated and stated that: *"There is no evidence for a set of health effects, from exposure to wind turbines, that could be characterized as a "Wind Turbine Syndrome"".*

3.2 Global Setbacks

Because environmental noise above certain levels is a recognized factor in a number of human health issues including learning, sleep and cognitive disruptions, hypertension, myocardial infarction and anxiety (Berglund and Lindvall, 1995; WHO 2009), many jurisdictions where wind turbines are being constructed have established noise restrictions and/or minimum setback distances in order to mitigate potential noise-based annoyance as well as operational effects related to shadow flicker, ice throw and structural failure.

A recent review of international policies and recommendations for wind turbine development prepared by the Minnesota Department of Commerce (Haugen, 2011) identified recommended and/or required distance setbacks for a number of jurisdictions in Europe, North America and Australia. Distance setbacks ranged from 200 to 2000 m

(for a total of 24 jurisdictions) and outdoor noise limits ranged from 30 to 65 dB(A) (for a total of 19 jurisdictions), with the majority set between 30 and 50 dB(A). These values are not absolute, but depend on a number of variables including wind speeds, location of placement (rural vs. urban) and time of day of noise exposure (day vs. night). What is more:

- Keith et al. (2008) concluded that: "*For quiet rural areas, in which annoyance reactions towards intruding noise may be augmented, this paper proposes noise mitigation if predicted wind turbine noise levels exceed 45 dBA at noise sensitive receptors* ";
- Verheijen et al. (2011) suggested a wind turbine noise level of Lden 45 dB (roughly comparable to 40 dBA) be adopted in the Netherlands;
- The Oregon Health Authority (2013) wrote that *"an outdoor L50 of 36 dBA is not expected to result in sleep disturbance, disturbance of communication, or annoyance in the general population";* and
- in Denmark the Danish Statutory Order on Noise from Wind Turbines (Danish EPA, 2011) states that wind turbine noise cannot exceed 42-44 dBA in the countryside or 37-39 dBA in sensitive areas (based on wind speeds between 6 and 8 m/s). The Danish guidance also states a distance setback of 4x turbine height and an infrasound guideline of 20dB indoors (Denmark 2011). These Danish audible noise setbacks (37-44 dBA) have also been suggested for use in Massachusetts (MassDEP and MDPH, 2012).

In the Province of Ontario, Canada, a number of appeals of approved wind projects have been heard by the Environmental Review Tribunal (ERT) on the grounds that the projects would cause serious harm to human health. Though the appellants provided evidence that they thought constituted serious harm to human health, none of the appeals were successful and the ERT concluded that projects regulated under provincial regulations do not cause serious harm (i.e., at the regulated setbacks of 40dBA and 550m).

4. Conclusions

As can be seen in this proceeding, many studies have been conducted world-wide to examine the relationship between wind turbines and possible human health effects. Based on the findings and scientific merit of these studies, our opinion is that the weight of evidence suggests that when sited properly, wind turbines are not related to adverse health effects. This opinion is supported by findings of (and has also been made by) a number of government health and medical agencies. While it is acknowledged that noise from wind turbines can be annoying to some and associated with some reported health effects (e.g., sleep disturbance), especially at sound pressure levels greater than 40

dB(A), given that annoyance appears to be more strongly related to visual cues and attitude than to noise itself, self reported health effects of people living near wind turbines are more likely attributed to physical manifestation from an annoyed state than from wind turbines themselves. In other words, it appears that it is the change in the environment that is associated with reported health effects and not a turbine-specific variable like audible noise or infrasound. The literature and our own experience highlight the need for informative discussions between wind power developers and community members in order to attempt to reduce the level of apprehension.

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