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Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada

Melissa L. Whitfield Aslund, Christopher A. Ollson, Loren D. Knopper*

Intrinsik Environmental Sciences Inc., 6605 Hurontario Street, Suite 500, Mississauga, Ontario, Canada L5T 0A3

HIGHLIGHTS

- Wind turbine noise-annoyance relationship used to predict annoyance in Ontario.
- Noise annoyance predicted to be <8% for non-participants <1 km from turbines.
- Predicted levels of wind turbine noise annoyance similar to that from traffic noise.
- Wind turbine noise annoyance not expected to exceed existing background levels.

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ABSTRACT

Wind turbines produce sound during their operation; therefore, jurisdictions around the world have developed regulations regarding the placement of electricity generating wind farms with the intent of preventing unacceptable levels of ‘community noise’ in their vicinity. However, as survey results indicate that the relationship between wind turbine noise and annoyance may differ from noise-annoyance relationships for other common noise sources (e.g., rail, traffic), there are concerns that the application of general noise guidelines for wind turbines may lead to unacceptably high levels of annoyance in communities. In this study, previously published survey results that quantified wind turbine noise and self-reported annoyance were applied to the predicted noise levels (from turbines and transformers) for over 8000 receptors in the vicinity of 13 planned wind power developments in the province of Ontario, Canada. The results of this analysis indicate that the current wind turbine noise restrictions in Ontario will limit community exposure to wind turbine related noise such that levels of annoyance are unlikely to exceed previously established background levels of noise-related annoyance from other common noise sources. This provides valuable context that should be considered by policy-makers when evaluating the potential impacts of wind turbine noise on the community.

1. Introduction

There are a number of studies that have explicitly examined the relationship between levels of wind turbine noise as predicted using internationally recognized outdoor sound propagation models such as standard method ISO 9613-2 (1996) and various self-reported indicators of human health and well-being (Bakker et al., 2012; Janssen et al., 2011; Pedersen and Persson Waye, 2004, 2007; Pedersen et al., 2009; Pedersen, 2011). These studies are based on the results of three surveys, two performed in Sweden (Pedersen and Persson Waye, 2004, 2007) and one performed in the Netherlands (Pedersen et al., 2009), with a total of 1755 respondents overall (Pedersen, 2011). In these surveys, residents living in proximity to wind turbines (i.e., <2.5 km) were asked to self-report their levels of annoyance (on a five point verbal scale ranging from 1—not annoyed to 5—very annoyed) as well as other potential indicators of disease, stress symptoms, sleep disturbance and subjective variables like visual cue, attitude and noise sensitivity. In an overall analysis of these datasets by Pedersen (2011), the only responses that were found to be statistically significantly ($p<0.05$) related to A-weighted wind turbine noise exposure in all three studies were annoyance (outdoors) and annoyance (indoors). No other measured variable (e.g., self reported evaluations of high blood pressure, cardiovascular disease, tinnitus, headache, sleep interruption, diabetes, tiredness, and reports of feeling tense, stressed, or irritable) was found to be directly related to wind turbine noise in all three datasets.

This reported correlation between wind turbine noise and annoyance is not unexpected as noise-related annoyance (described

* Corresponding author. Tel.: +1 905 364 7800x210.
E-mail addresses: lknopper@intrinsik.com, melissa.whitfield@live.ca (L.D. Knopper).

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by Berglund and Lindvall (1995) as a "feeling of displeasure evoked by a noise") has been extensively linked to a variety of common noise sources such as rail, road, and air traffic (Berglund and Lindvall, 1995; Laszlo et al., 2012; WHO Europe, 2011). Although annoyance is considered to be the least severe potential impact of community noise exposure (Babisch, 2002; WHO Europe, 2011), it has been hypothesized that sufficiently high levels of noise-related annoyance could lead to negative emotional responses (e.g., anger, disappointment, depression, or anxiety) and psychosocial symptoms (e.g., tiredness, stomach discomfort and stress) (Fields et al., 2001, 1997; Job, 1993; WHO Europe, 2011; Öhrström, 2004; Öhrström et al., 2006). Therefore, regulations exist in many jurisdictions around the world to limit community noise exposure from stationary sources (e.g., factories) as well as road, rail, and air traffic in order to curtail community levels of annoyance and more severe impacts of community noise exposure. It is important to emphasize that the existence of these guidelines has not eliminated community noise annoyance and noise related annoyance remains prevalent in many communities. For instance, results of national surveys in Canada and the U.K. by Michaud et al. (2005) and Grimwood et al. (2002), respectively, suggest that annoyance from noise (predominantly traffic noise) may impact approximately 8% of the general population. Even in small communities in Canada (i.e., <5000 residents where traffic is relatively light compared to urban centers), Michaud et al. (2005) reported that 11% of respondents were moderately to extremely annoyed by traffic noise. Since wind turbines represent an additional source of noise to the community, many jurisdictions have also developed wind turbine siting regulations based on existing noise guidelines for the aforementioned common community noise sources (see examples in Haugen, 2011). For example, in Ontario, Canada, noise limits for wind turbines and associated noise sources (i.e., transformer substations) are effectively set to 40 dB(A) (see details in Section 2) for non-participating receptors (i.e., those without economic benefit from the project). This limit is in compliance with the WHO recommendations to prevent annoyance during the day (i.e. $\leq$55 dB(A) outdoors, Berglund and Lindvall, 1995) and sleep disturbance at night (i.e. $\leq$40 dB(A) outdoors, WHO, 2009).

For common noise sources such as airport and traffic noise, noise-annoyance dose response relationships exist in the literature that are described by cubic functions showing minimal levels of annoyance at low noise levels and rapid increases in annoyance past a certain level of noise exposure (WHO Europe, 2011). It has been proposed that annoyance from wind turbine noise could be described by a similar function (Janssen et al., 2011). However, key differences have been noted between the parameters that define the wind turbine noise annoyance dose response relationship and those of other more common noise sources (Janssen et al., 2011). For instance, people receiving an economic benefit from the wind turbines report almost no annoyance from wind turbine noise even though they are exposed to the highest noise levels (Bakker et al., 2012; Janssen et al., 2011; as reviewed by Knopper and Ollson, 2011; Pedersen et al., 2009). In contrast, people who do not receive an economic benefit from the turbines report higher levels of annoyance at lower sound pressure levels than would be predicted for other community noise sources (Bakker et al., 2012; Janssen et al., 2011; Pedersen et al., 2009). It has been hypothesized that the differences in dose-responses could be driven by numerous factors including the modulating character of audible (and inaudible) wind turbine noise and/or subjective factors such as visual impact, attitudes towards wind turbines (e.g., see Bakker et al., 2012; Janssen et al., 2011; Pedersen et al., 2009), personality traits (Taylor et al., 2012, 2013) and conflict between the community and the wind farm developers (Shepherd et al., 2011). Additionally, traditional noise dose-response relationships for rail, road, and air traffic were derived using data from urban areas, where residents may have less of an expectation of quiet/more tolerance for noise than residents of rural areas where turbines are typically constructed. Based on the apparent differences between community response to wind turbine noise and other noise sources, concerns have been raised by some that the noise-related siting restrictions that have been developed for wind turbines based on traditional noise annoyance dose-response relationships may not adequately protect residents living near wind turbines from noise-related annoyance.

In light of this concern, this study was conducted to consider how the permitted wind turbine noise levels in Ontario, Canada might relate to predicted levels of annoyance based on a wind turbine specific dose-response relationship reported in the literature. Specifically, modeled noise levels and distance to the nearest wind farm related noise source were compiled for over 8000 individual receptor locations (i.e., buildings, dwellings, campsites, places of worship, institutions and/or vacant lots) from 13 wind power projects in the province of Ontario, Canada that had been approved since 2009 or were under Ministry of the Environment (MOE) review as of July 2012. This information was then compared to the wind turbine noise specific dose-response relationships for self-reported annoyance from Pedersen et al. (2009) and Bakker et al. (2012) using data collected from 725 survey respondents living in the proximity of wind turbines (<2.5 km) in the Netherlands. This relationship was selected because Pedersen et al. (2009) and Bakker et al. (2012) provided the most detailed information on the responses of both participating and non-participating receptors, as well as information for both indoor and outdoor annoyance for non-participating receptors. Although this excludes the relationships developed from two Swedish survey datasets (Pedersen and Persson Waye, 2004, 2007), a comparison in Pedersen et al. (2009) between the Dutch and Swedish studies suggests that the results are very similar. A discussion of the relationship between predicted noise levels, distance from wind turbines and predicted rates of community annoyance is provided and the predicted rates of annoyance from wind turbines are compared to established rates of annoyance from other community noise sources in the general Canadian population and elsewhere. It is acknowledged that social and geographical differences exist between the Netherlands and the province of Ontario that may alter some aspects of this dose-response relationship. Despite these limitations, and in the absence of Ontario specific data, it was assumed that this model provides a more realistic and conservative prediction of potential annoyance from wind turbine noise in Ontario than was previously available from relationships developed specifically for traffic or stationary sources.

2. Methods

In Ontario, both distance and noise-based requirements must be met in order for a wind power project to be in compliance with provincial regulations (MOE, 2010). Specifically, for potential non-participating noise receptor locations in Ontario the distance to the nearest wind turbine must exceed 550 m and the total predicted noise levels from all wind farm related sources (i.e., wind turbines and associated transformer substations) at that receptor location must not exceed established sound level limits of 40 dB(A) to 51 dB(A) (Table 1). There is no distance setback for the transformer substations, but the noise limits still apply. A range of noise level limits is permitted in order to account for situations when wind turbine noise is likely to be somewhat masked by higher background noise (i.e., in urban areas or during high wind speed periods (up to 10 m/s), see Table 1). However; due to the acoustic emissions profile of most wind turbines with