# Wind Turbine Noise, Sleep Quality, and Symptoms of Inner Ear Problems


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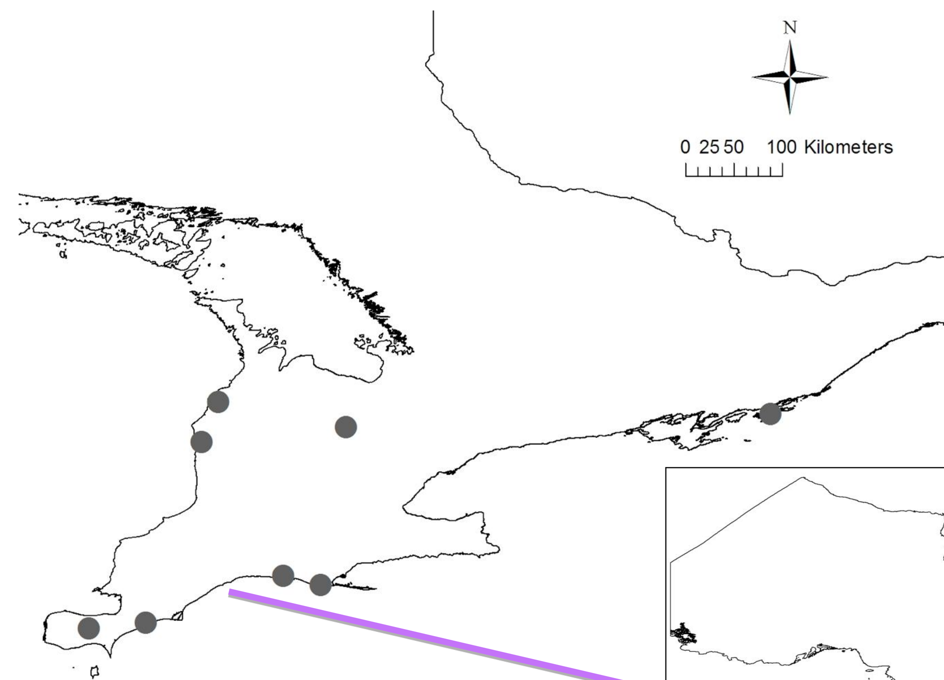
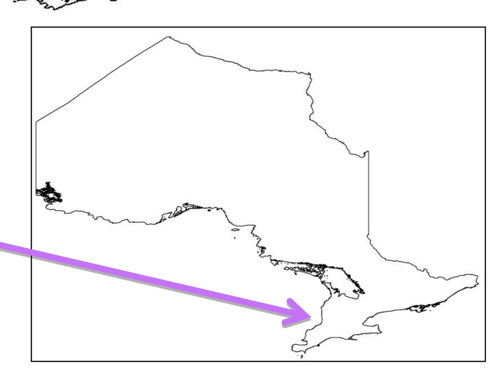
## Introduction

Wind turbines are a form of renewable energy, which generate electricity from wind energy, a practice dating back over 100 years. The production of electricity from the movement of wind turbine motor blades creates both mechanical and aerodynamic noise. This type of environmental noise is a growing public health concern, especially for residents living close to wind turbines. A body of evidence now exists to suggest that wind turbine noise can impair health and contribute to annoyance and sleep disturbance. However, in Ontario, little is known about how wind turbines impact people living in their vicinity. This investigation was a cross-sectional study involving eight Ontario communities that contain ten or more wind turbines. This study investigated the impact of wind turbine noise, using distance as a surrogate measure, on quality of life (both physical and mental health) and sleep disturbance in residents living close to wind turbines. Dose-response relationships were examined in an attempt to investigate acceptable exposure levels and appropriate setback distances for wind turbines.



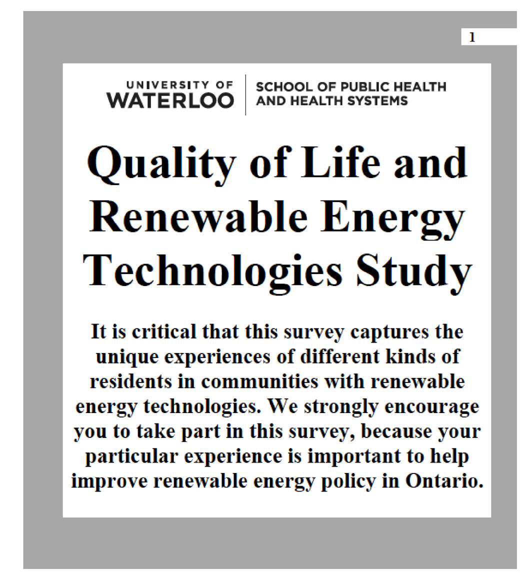

*Eight wind farm communities analyzed in Ontario. Wind farm sites are shown in grey. The province of Ontario is shown (inset).*
(Quick et al.– submitted)



*Province of Ontario map obtained from Statistics Canada.*

## Methods

For this cross-sectional study, the "Quality of Life and Renewable Energy Technologies Study" survey was used to measure the impact of wind turbine noise on health. Using Canada Post's Unaddressed Admail Service, surveys were sent out to 4876 residences in Ontario counties that contain 10 or more wind turbines. Completed surveys were returned to the University of Waterloo by study participants using Canada Post's Business Reply Mail Service. Members of the Renewable Energy Technologies and Health team coded and entered the results into Microsoft Excel as surveys were received. Survey respondents' self-reported addresses (i.e. full street addresses with postal codes) were entered into Google Maps to determine the location of each residence. All analyses were performed using SAS 9.22. Descriptive and multivariate analyses were performed to investigate the effect of the main independent variable of interest (distance to nearest wind turbine) on the various outcome measures.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**Quality of Life and Renewable Energy Technologies Study**

**It is critical that this survey captures the unique experiences of different kinds of residents in communities with renewable energy technologies. We strongly encourage you to take part in this survey, because your particular experience is important to help improve renewable energy policy in Ontario.**


| Distance (m) from Residence to Nearest Wind Turbine (mean) | | | | |
|---|---|---|---|---|
| Parameter | 0-999.99 (700.62) | 1000-1999.99 (1426.96) | 2000-3999.99 (3044.30) | >4000 (9190.84) |
| Sample Size | 70 | 80 | 103 | 143 |
| Mean Age | 52.32 ( 14.08) | 53.95 ( 14.82) | 55.99 ( 16.41) | 57.09 ( 14.15) |
| Male/Female | 39/30 | 43/37 | 50/52 | 72/68 |
| Mean Time in Home[1] | 18.38 ( 13.78) | 20.12 ( 15.19) | 19.76 ( 15.20) | 18.47 ( 16.21) |
| Mean # of Wind Turbines within 2000 m | 8.49 ( 6.47) | 3.41 ( 2.46) | 0 | 0 |

[1] Years that study participants have lived at current residence

*Demographic data of study participants from eight WT communities combined.*

## Noise from Wind Turbines

Wind turbines produce two main types of noise:

1. **Mechanical noise** - mainly motor noise from within the turbine (many ways to reduce this)

2. **Aerodynamic noise** – mainly from the flow of air around the blades (sound pressure levels increase with tip speed and size); is the dominant source of noise from wind turbines and results in a "swishing" or "thumping" noise

Aerodynamic noise is present at all frequencies, from infrasound (frequencies below 20Hz) to low frequency (frequencies below 200 Hz) to the normal audible range. In most cases, the sound from wind turbines is described as infrasound. Although infrasound is usually inaudible, at high enough sound pressure levels, it can be audible to some people.

Studies have shown that high sound pressure levels (loudness) of audible noise and infrasound have been associated with learning, sleep and cognitive disruptions, stress, and anxiety (Leventhall et al., 2003; WHOE, 2009; Knopper & Ollson, 2011). More specifically, studies have suggested that wind turbine noise (i.e. low-frequency sound energy below 20Hz) can impact health, though this is still an area under debate (Pierpont, 2009; Salt & Hullar, 2010).

Research also suggests that some inner ear components (such as the outer hair cells) may respond to infrasound at the frequencies and sound levels generated by wind turbines. Therefore, there is a possibility that exposure to the infrasound component of wind turbine noise could influence the physiology of the ear leading to changes in the exposed individual (Salt & Hullar, 2010).

Source: http://www.psmag.com/environment/noise-complaints-draw-opposition-to-wind-farms-26673/


**Acknowledgements:**
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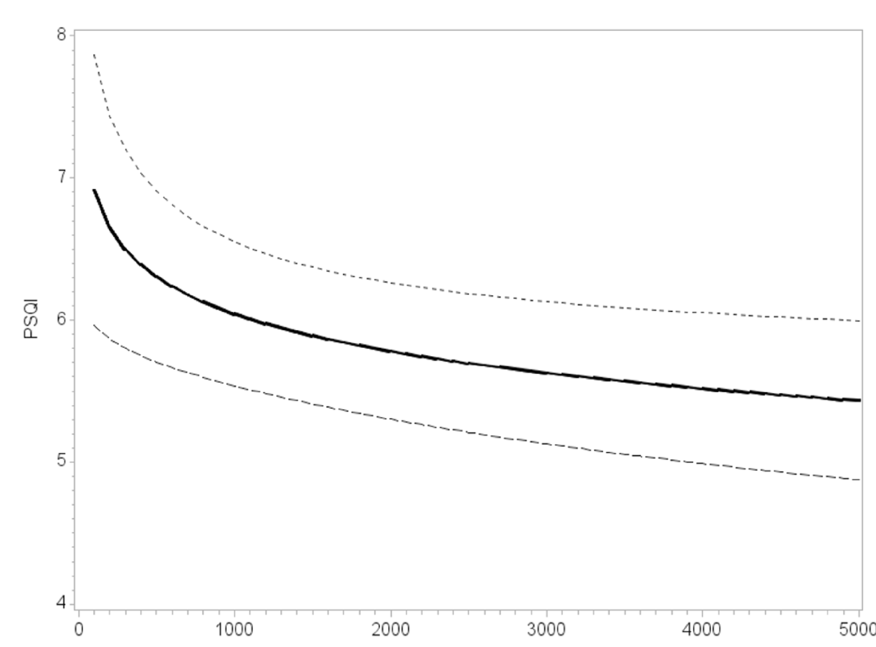
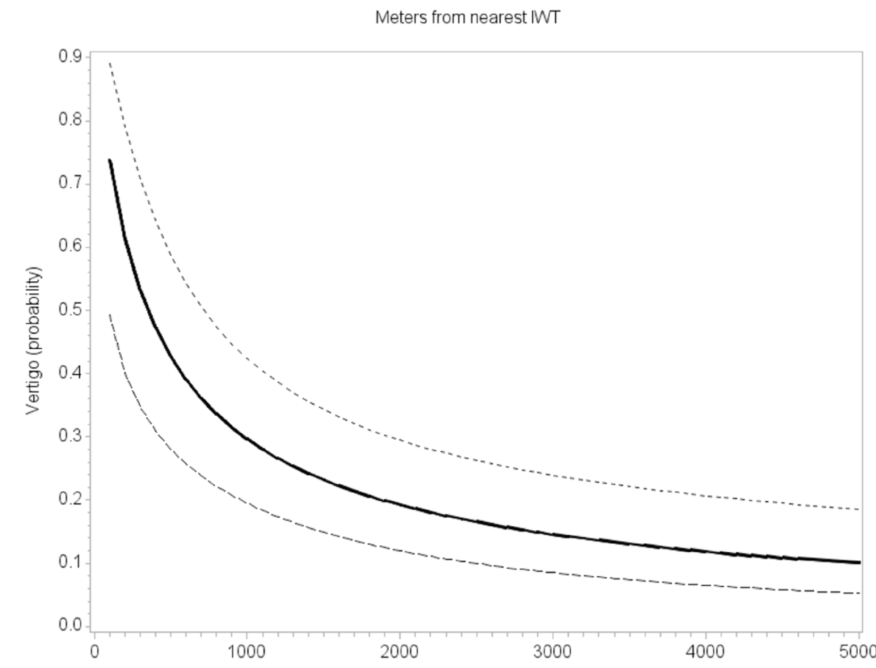
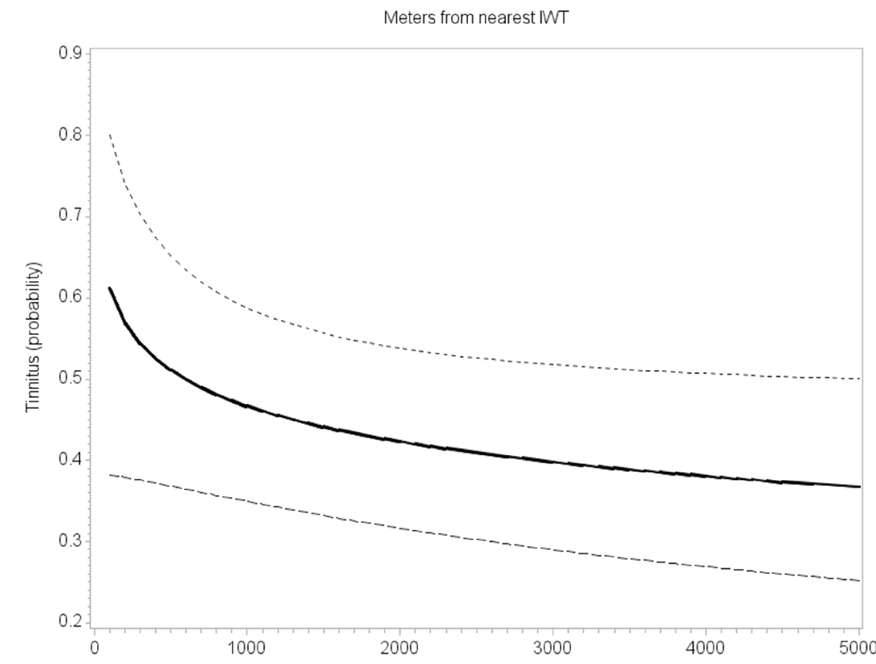



***PSQI - ln(distance) relationship (P=0.0096). Graph shows modeled mean and upper and lower 95% confidence intervals.***




***Vertigo - ln(distance) relationship (P<0.001). Graph shows modeled mean and upper and lower 95% confidence intervals.***




***Tinnitus - ln(distance) relationship (P=0.0755). Graph shows modeled mean and upper and lower 95% confidence intervals.***

## Results and Discussion

The data obtained for use in this study were collected between February 1st and May 31st, 2013. In total there were 412 surveys returned; 16 of these survey respondents did not provide their home address. Therefore, 396 surveys were included in the analysis.

The relationship between ln(distance) (as a continuous variable) and mean Pittsburgh Sleep Quality Index (PSQI) was found to be statistically significant (P=0.0096) when controlling for age, gender and county. This relationship shows that as the distance increases (move further away from a wind turbine), PSQI decreases (i.e. sleep improves) in a logarithmic relationship. Multivariate analysis involved assessing distance to the nearest wind turbine as both distance and ln(distance). In all cases, ln(distance) resulted in improved model fit.

The relationship between vertigo and ln(distance) was statistically significant (P<0.001) when controlling for age, gender, and county. The relationship between tinnitus and ln(distance) approached statistical significance (P=0.0755). Both vertigo and tinnitus were worse among participants living closer to wind turbines.

Spearman's rank correlation coefficients ($r_s$) between PSQI, vertigo and tinnitus are shown below. All relationships were found to be positive and statistically significant. The strongest correlation was seen between the variables 'tinnitus' and 'vertigo' ($r_s$=0.2).

| | Vertigo | Tinnitus | PSQI |
|---|---|---|---|
| Vertigo | 1 | 0.25 (p<0.0001) | 0.22 (p<0.0001) |
| Tinnitus | 0.25 (p<0.0001) | 1 | 0.11 (p=0.0392) |
| PSQI | 0.22 (p<0.0001) | 0.11 (p=0.0382) | 1 |

In conclusion, relationships were found between ln(distance) and PSQI, ln(distance) and self-reported vertigo and ln(distance) and self-reported tinnitus. Study findings suggest that future research should focus on the effects of wind turbine noise on sleep disturbance and symptoms of inner ear problems.

| County | Wind Farm | Total Surveys Sent |
|---|---|---|
| Bruce | Enbridge | 828 |
| Chatham-Kent | Raleigh | 415 |
| Dufferin | Melancthon | 944 |
| Elgin | Erie Shores | 726 |
| Essex | Comber | 1222 |
| Frontenac | Wolfe Island | 155 |
| Huron | Kingsbridge | 473 |
| Norfolk | Frogmore/Cultus /Clear Creek | 113 |
| **TOTAL** | | **4876** |

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