Annoyance can represent a serious degradation of health: wind turbine noise a case study

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Annoyance is often discounted as a health concern. Wind turbine noise is perceived to be more annoying than other equally loud sources of sound. The Ontario government commissioned a report which concludes a non-trivial percentage those exposed to wind turbine sound will be highly annoyed which can be expected to contribute to stress related health impacts. Our research in Ontario, Canada documents some individuals living in the environs of wind turbines report experiencing physiological and psychological symptoms, reduced quality of life, degraded living conditions, and adverse social and economic impacts. Some families have abandoned their homes or negotiated financial agreements with wind energy developers. An Ontario Environmental Review Tribunal considered a wide body of evidence including expert testimony and found wind turbines can harm humans if placed too close to residents. Evidence including peer reviewed literature, case

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reports, freedom of information documents and expert testimony are presented which support the conclusion that annoyance can represent a serious degradation of health.

1 INTRODUCTION

Until recently the impacts of noise induced annoyance have been underestimated. Sound which is perceived by humans to be annoying can result in serious harm to human health. Members of society including regulating authorities, industry, health professionals, and the general public often confuse the health effect of "annoyance" with the colloquial usage of the term. Failing to understand that annoyance represents a risk to public health may result in noise regulations which enable serious harm to human health.

Industrial wind turbines represent a new source of sound which is perceived to be more annoying than other sources of noise at comparable sound levels. Increasingly, there are individuals exposed to wind turbine noise who report experiencing adverse health effects including annoyance, physiological, psychological symptoms and reduced quality of life.

This paper explores the impacts of industrial wind turbine annoyance and discusses reviewed literature, case reports, freedom of information documents and expert testimony which support the conclusion that annoyance must be considered a risk to humans and can represent a serious degradation of health.

2 TERMINOLOGY: NOISE ANNOYANCE AND HEALTH

The study of noise and its health effects is a relatively recent science which continues to evolve. In recent years the health effects of hazardous noise exposure are now considered to be an increasingly important public health problem[1]. In spite of these acknowledgements the health impacts of sound are often misunderstood and/or discounted by authorities, health professionals and the general public. This lack of understanding is in part due to a failure to apply accepted definitions of health and/or fully comprehend the human health impacts of noise exposure.

2.1 Fundamental Rights and Definition of Health

When assessing the health impacts of noise exposure it is important to apply an authoritative definition of health. The World Health Organization (WHO) definition of health has been accepted by many jurisdictions including the Canadian federal, provincial, and territorial governments and health officials:[2] "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity[3]." The WHO "… recognizes the enjoyment of the highest attainable standard of health as one of the fundamental rights of every human being[4]."

Despite being widely accepted the WHO definition of health is frequently overlooked when assessing the health impacts of noise.

2.2 Sound versus Noise

Sound is not the same as noise. The WHO defines noise as "unwanted sound"[5] perceived by humans. Sound meters can assess sound; however, humans assess "noise". Sound becomes a risk to human health when it is considered to be noise.

Industrial noise guideline limits are typically designed to protect humans from direct health effects such as hearing loss. Community noise limits tend to be lower in order to protect humans

from effects originating in the indirect causal pathway. Noise of a moderate level acts via an indirect pathway and can have health outcomes similar to those caused by high noise exposures on the direct pathway[4]. Specific health effects in the indirect pathway to be considered when setting community noise limits include: interference with communication; sleep disturbance effects; cardiovascular and psycho-physiological effects; performance reduction effects; effects on social behaviour and annoyance[5].

2.3 Annoyance: Health versus Colloquial Terminology

Professionals responsible for safeguarding human health must understand that noise annoyance should not be mistaken with the everyday expression of annoyance. Annoyance is acknowledged to be an adverse health effect[6,7,8]. Suter[9] notes:

> "'Annoyance" has been the term used to describe the community's collective feelings about noise ever since the early noise surveys in the 1950s and 1960s, although some have suggested that this term tends to minimize the impact. While "aversion" or "distress" might be more appropriate descriptors, their use would make comparisons to previous research difficult. It should be clear, however, that annoyance can connote more than a slight irritation; it can mean a significant degradation in the quality of life. This represents a degradation of health in accordance with the WHO's definition of health, meaning total physical and mental well-being, as well as the absence of disease."

Annoyance has been defined as "… a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them[5] …". The severity of the adverse effect is determined by the degree of exposure. For example transient noise induced annoyance is unlikely to result in long term adverse effects while chronic annoyance can have serious consequences to human health.

2.4 Annoyance: A Serious Risk to Human Health

The recognition of noise as a serious health hazard as opposed to a nuisance is a recent development[1]. Until recently the health consequences of noise induced annoyance have been underestimated. The US Environmental Protection Agency states "…"annoyance" can have major consequences, primarily to one's overall health[10]."

Self evaluation using questionnaires is an accepted methodology which has been utilized in studies to assess the effects of noise annoyance. A WHO epidemiology study assessed noise annoyance and documented significantly elevated relative risks exist both in the cardiovascular system, the respiratory system, and the musculoskeletal system as well as by depression. The study concluded that for chronically strong annoyance a causal chain exists between the three steps health – strong annoyance – increased morbidity[11].

Other symptoms associated with annoyance from various noise sources include: stress, sleep disturbance, headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, tinnitus, anxiety, heart ailments, and palpitation[12,13,14]. Chronic severe annoyance induced by noise must be classified as a serious human health risk[15].

2.5 Annoyance and Noise Management

The WHO published *Guidelines for Community Noise*[5] which identifies annoyance as a "critical health effect" and provides the following framework for managing noise such that human health and well-being are protected. Noise limits should be based on annoyance responses to noise and should protect humans indoors as well as outdoors. Human exposure to noise should be based on science based dose response relationships. "The capacity of a noise to induce annoyance depends upon many of its physical characteristics, including its sound pressure level and spectral characteristics, as well as the variations of these properties over time." Different dose-response relations for different types of noise demonstrate that different sources of noise can cause different annoyance effects at equal LAeq, 24h values.

2.6 Wind Turbines Are More Annoying

Wind turbines can affect the living environment of exposed residents. Wind turbines are elevated sound sources which can intrude both visually and aurally into private space[16]. Modern wind turbines are typically over 130 meters tall and produce approximately 105 dBA of sound power at source.

Peer-reviewed studies consistently show wind turbine sound is perceived to be more annoying than transportation noise or industrial noise at comparable sound pressure levels[16]. Annoyance starts at wind turbine dBA sound pressure levels in the low 30's and rises sharply at 35 dBA.

Wind turbine amplitude modulation[17], audible low frequency noise[18, 21], infrasound[19], tonal noise, impulse noise[20], lack of nighttime abatement[16], visual and economic impacts have been identified as plausible causes of wind turbine induced annoyance and/or other adverse effects.

Wind turbine compliance noise audits are typically based on an averaged "A"-weighted metric which is unsatisfactory for complaints of cyclical amplitude modulation and low frequency noise[22]. Furthermore wind turbine noise guidelines typically do not address the lack of night time abatement.

2.7 The Well Known Effects of Annoyance by Noise

"Environmental noise acts as a stressor at night by disturbing sleep and via annoyance (or bothering) during the day[11]." The Wind Turbine Noise (2011) post–conference report[23] states,

> "The main effect of daytime wind turbine noise is annoyance. The night time effect is sleep disturbance. These may lead to stress related illness in some people. Work is required in understanding why low levels of wind turbine noise may produce affects which are greater than might be expected from their levels."

Complaints are not uncommon from individuals exposed to wind turbine sound[22,24]. Wind turbines sited in proximity to humans has resulted in complaints and reports of adverse health effects including annoyance and/or sleep disturbance and/or stress related health impacts and/or reduced quality of life[25,26,27,28,29,30,31,32,33,34].

Dr. Nina Pierpont documented symptoms reported by individuals exposed to wind turbines which 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[35].

In 2009 The American Wind Energy Association and Canadian Wind Energy Association funded a panel literature review which determined wind turbine symptoms documented by Dr. Pierpont "… are not new and have been published previously in the context of "annoyance"" and are the "… well-known stress effects of exposure to noise …[36]". A coauthor of this review stated in a separate analysis: "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[37] …". The contents of these two references were reaffirmed by witnesses testifying under oath during a 2011 Ontario Environmental Review Tribunal[38].

2.8 Wind Turbines in Ontario

The introduction of wind turbines into Ontario, Canada is a relatively recent development. Ontario wind turbines are typically sited in quiet rural settings which frequently have low population densities and can have ambient sound levels below 30 dBA[39].

Ontario Ministry of Environment guidelines are based on an averaged "A"-weighted metric and permit noise of 40 dBA up to 51 dBA (formerly 53 dBA) depending on wind speed. Noise limits are measured at the façade of a receptor (i.e. home). Ontario does not have limits for wind turbine noise inside homes or elsewhere on private property. Until 2011 the Ontario Ministry of Environment did not have a scientifically accepted field methodology to measure wind turbine noise to determine compliance or non compliance with approval limits[40]. In August 2011 the Ontario Ministry of Environment introduced a "Compliance Protocol for Wind Turbine Noise" which explicitly excludes consideration of "health effects".

Internal Ontario Ministry of Environment correspondence, obtained through a Freedom of Information Request, states: "It appears compliance with the minimum setbacks and the noise study approach currently being used to approve the siting of WTGs will result or likely result in adverse effects[39] …". In December 2011 the Ontario Ministry of Environment released a consultant report which concludes the sound from wind turbines, at the levels experienced at typical receptor distances in Ontario, is "… expected to result in a nontrivial percentage of persons being highly annoyed … research has shown that annoyance associated with sound from wind turbines can be expected to contribute to stress related health impacts in some persons[41]."

There have been numerous noise and health complaints coinciding with the commencement of operations of some Ontario wind turbines projects. In some cases families reporting adverse effects have been billeted at the wind energy developer's expense[42]. Other families have abandoned their homes or been bought out by wind energy developers[31]. In response to the lack of vigilance monitoring in Ontario, volunteers established WindVOiCe in March 2009. WindVOiCe is a self reporting health survey which follows the principles of Health Canada's Canada Vigilance Programs for reporting adverse events for prescription and nonprescription products, vaccines and other[30].

Sleeplessness and headaches are among the most common health effects reported in other case studies[21]. The results of the WindVOiCe survey plots the predicted probability of; sleep disturbance (Figure 1), excessive tiredness (Figure 2) and headaches (Figure 3) by distance to industrial wind turbine. The predicted probability of these health effects diminishes with increased separation distance between the wind turbine and the participant's property. Nissenbaum et al.[29] also documented a reduction of sleep effects as wind turbine separation distances increased. These "effect versus distance relationships" are consistent with the physics of sound decay through absorption by ground and the atmosphere.

WindVOiCe also collected comments which included participant descriptions of their perception of wind turbine noise and visual impacts such as shadow flicker. These comments provide insight into effects that unwanted sound as perceived by humans can have on individuals.

Statistics from health surveys often do not fully convey the degree of impact that an exposure can have on an individual's physical mental and social well-being. The following case study summarizes the experience of an Ontario couple that resided in proximity to wind turbines and illustrates the impact that annoyance can have on an individual's overall health and well-being.

3 RESULTS

In December 2008 a new wind turbine project began operations in proximity to a couple's home in rural Ontario. Consultants for the wind turbine developer had prepared a noise modeling assessment. The Environmental Screening Report for the project stated "…environmental modelling technically reviewed and approved by the MOE has predicted sound levels to be within the applicable MOE noise guidelines for wind turbines[43] …" The wind turbine facility was issued a Certificate of Approval by the Ontario Ministry of Environment.

Prior to the commencement of operations the couple had a positive attitude towards wind energy projects. The couple perceived wind energy to be "… good for the environment [44]…" and considered wind turbines visually "majestic"[45]. The couple did not have concerns about economic impacts associated with the project and were supportive of the neighbors who were hosting the turbines[44]. The couple's home represented one of their largest financial investments. During the construction phase of the wind turbine project the couple continued to invest in major improvements to their property. The couple did not have expectations that the wind turbines would have negative impacts[31,44].

After the wind turbine facility began operations the couple's living conditions became adversely affected. The turbines were orientated such that shadow flicker did not present an issue on the couple's property. Sound produced by the wind turbines was identified to be the source of the disturbance resulting in noise induced annoyance. The couple experienced sleep disturbance for days at a time depending on the conditions. Other physiological and psychological symptoms also became apparent and the couple's quality of life was negatively altered. The couple complained to authorities and the wind energy developer about the noise from the wind turbines and was informed that the facilities were operating in compliance. The couple also contacted various agencies including public health authorities with little or no results.

The wind turbine noise was at times more perceptible indoors than outdoors indicating a low frequency noise issue. Eventually investigations by Ontario Ministry of Environment personnel and a number of sound studies were conducted at the home. The wind turbine sound was judged to; be tonal, contain low frequency components, and routinely produce an audible amplitude modulation.

Perceptible low frequency wind turbine noise inside the couple's home made the building uninhabitable. The wind energy developer attempted to mitigate the noise by shutting down up to five surrounding turbines at night. Despite these mitigation measures the couple continued to experience sleep disturbance and other physiological and psychological symptoms. Attempts to achieve restorative sleep included the couple sleeping outside the home in a tent where the noise was less disturbing. (Figure 4)

In March 2009 the couple retained legal counsel in hopes of resolving the issues caused by the wind turbine noise. By June 2009 the couple had negotiated an agreement with the wind

energy developer to purchase the home. The agreement is reported to contain non disclosure conditions which prevent the couple from discussing specific details of their experience. The couple experienced additional stress from leaving a home they had loved and having to locate and purchase another home under a compressed time line.

4 DISCUSSION AND CONCLUSIONS

Annoyance is one of the most common and frequently under appreciated health effects of noise. Annoyance should not be discounted as a health effect as it can have major consequences to one's overall health. The case study and references presented in this paper support the conclusion that unwanted sound that results in noise induced annoyance can represent a serious degradation of health as defined by the WHO.

Those responsible for the production and regulation of noise need to understand the significance of annoyance and adopt strategies to prevent it. Noise limits should be established to protect against annoyance, both indoors and outdoors, using authoritative noise management techniques. Psycho-acoustical impacts of a noise source must be assessed in context to the soundscape being affected. Limits should be based on the physical characteristics of the specific sound source. Sound pressure level, spectral characteristics, as well as the variations of these properties over time should be assessed when determining the capacity of a noise to induce annoyance.

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Fig. 1 – Predicted probability of sleep disturbance by distance to industrial wind turbine (95% upper and lower confidence limits)Proc Genmod (logit link; binimoial distribution). Sleep = ln(distance) + sex + intercept. p(ln distance) = .1015.

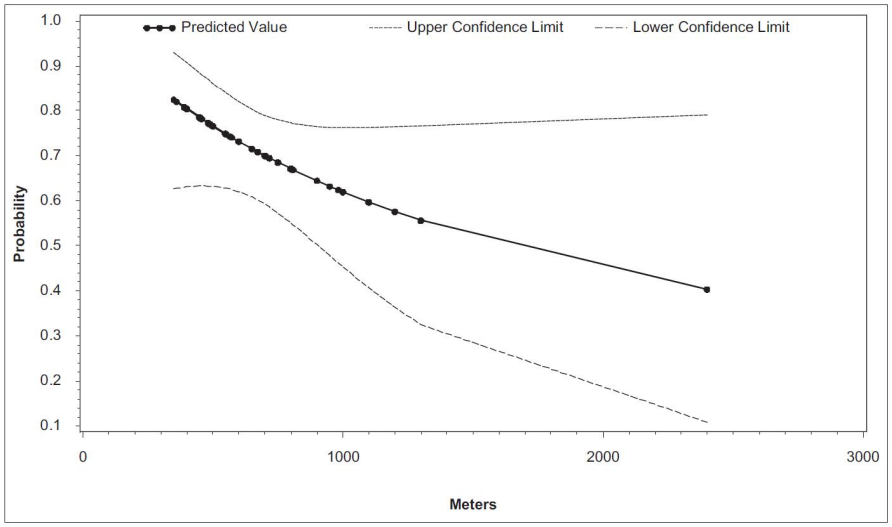

Fig. 2 – Predicted probability of excessive tiredness by distance to industrial wind turbine (95% upper and lower confidence limits) Proc Genmod (logit link; binimoial distribution). Excessive tiredness = ln(distance) + sex + intercept. p(ln distance) = .1005.

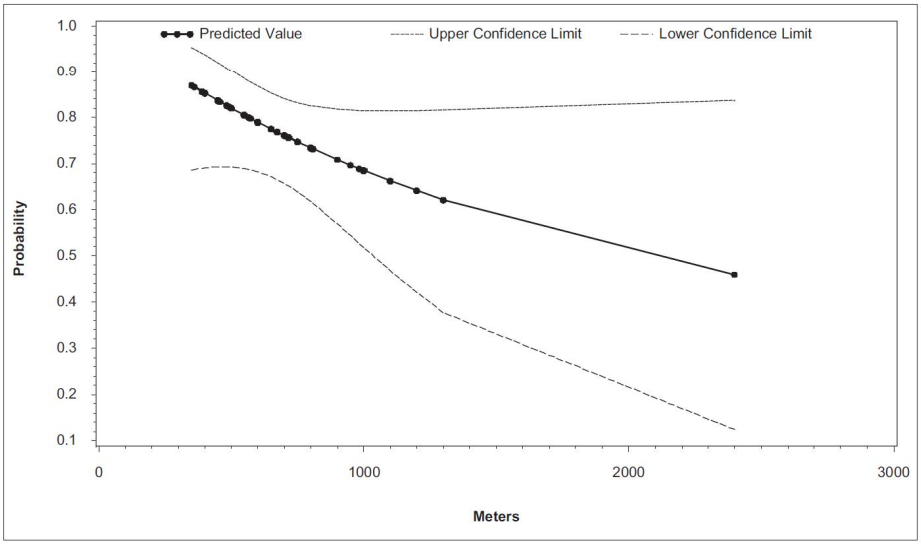

Fig. 3 – Predicted probability of headaches by distance to industrial wind turbine (95% upper and lower confidence limits)Proc Genmod (logit link; binimoial distribution). Headaches = ln(distance) + sex + intercept. p(ln distance) = .1837.

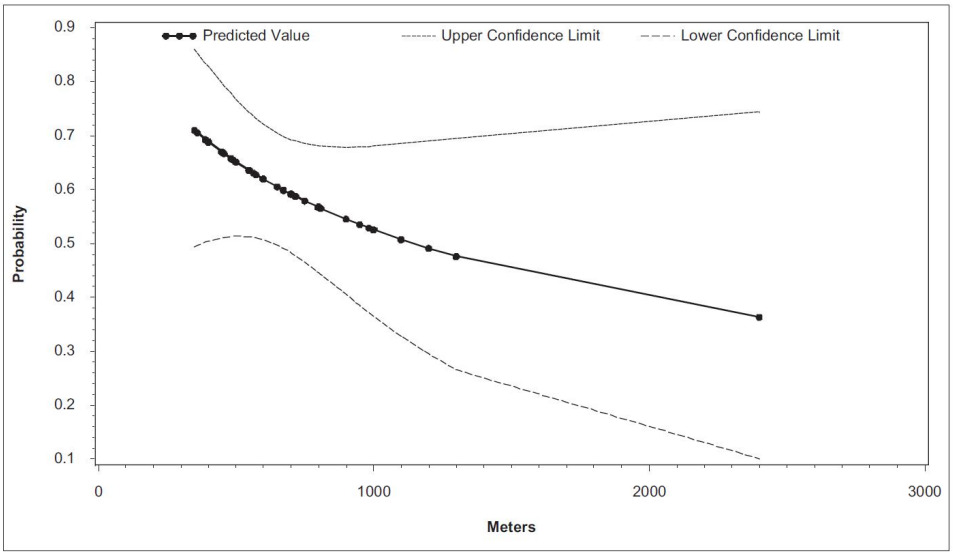

Fig. 4 – Escaping wind turbine noise. Ontario, Canada