Industrial Wind Turbines and Health:
Wind Turbines Can Harm Humans if too close to Residents[1]

A summary of some of the peer reviewed articles and conference papers, abstracts and other citations, regarding impairment of health in general and relating to industrial wind turbines[2]

Compiled by Carmen Krogh, BScPharm
April 2014[3]

PEER REVIEWED

Ambrose, Stephen E.; Rand, Robert W.; and Krogh, Carmen M. E.
Wind Turbine Acoustic Investigation: Infrasound and Low-Frequency Noise
A Case Study DOI: 10.1177/0270467612455734
Bulletin of Science Technology & Society published online 17 August 2012
http://bst.sagepub.com/content/early/2012/07/30/0270467612455734

Abstract
Wind turbines produce sound that is capable of disturbing local residents and is reported to cause annoyance, sleep disturbance, and other health-related impacts. An acoustical study was conducted to investigate the presence of infrasonic and low-frequency noise emissions from wind turbines located in Falmouth, Massachusetts, USA. During the study, the investigating acousticians experienced adverse health effects consistent with those reported by some Falmouth residents. The authors conclude that wind turbine acoustic energy was found to be greater than or uniquely distinguishable from the ambient background levels and capable of exceeding human detection thresholds. The authors emphasize the need for epidemiological and laboratory research by health professionals and acousticians concerned with public health and well-being to develop effective and precautionary setback distances for industrial wind turbines that protect residents from wind turbine sound.

Bernert RA, and Joiner TE
Sleep disturbances and suicide risk: A review of the literature.
Neuropsychiatr Dis Treat. 2007 December; 3(6): 735–743. PMC ID: PMC2656315
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2656315/

Abstract
A growing body of research indicates that sleep disturbances are associated with suicidal ideation and behaviors. This article provides a critical review of the extant literature on sleep and suicidality and addresses shared underlying neurobiological factors, biological and social zeitgebers, treatment implications, and future directions for research. Findings indicate that suicidal ideation and behaviors are closely associated with sleep complaints, and in some cases, this association exists above and beyond depression. Several cross-sectional investigations indicate a unique association between nightmares and suicidal ideation, whereas the relationship between insomnia and suicidality requires

[1] Excerpted from Case Nos.: 10-121/10-122 Erickson v. Director, Ministry of the Environment Environmental Review Tribunal, Decision, p 207 "This case has successfully shown that the debate should not be simplified to one about whether wind turbines can cause harm to humans. The evidence presented to the Tribunal demonstrates that they can, if facilities are placed too close to residents. The debate has now evolved to one of degree."
[2] This summary focuses on references 2010 to April 2014 associated with risks to health. References are not intended to be exhaustive.
[3] Any errors or omissions are unintended

further study. Underlying neurobiological factors may, in part, account for the relationship between sleep and suicide. Serotonergic neurotransmission appears to play a critical role in both sleep and suicide. Finally, it remains unclear whether or not sleep-oriented interventions may reduce risk for suicidal behaviors. Unlike other suicide risk factors, sleep complaints may be particularly amenable to treatment. As a warning sign, disturbances in sleep may thus be especially useful to research and may serve as an important clinical target for future suicide intervention efforts.

Bronzaft, Arline L.
The Noise from Wind Turbines: Potential Adverse Impacts on Children's Well-Being
Bulletin of Science Technology & Society 2011 31: 256, DOI: 10.1177/0270467611412548.
http://bst.sagepub.com/content/31/4/291

Abstract
Research linking loud sounds to hearing loss in youngsters is now widespread, resulting in the issuance of warnings to protect children's hearing. However, studies attesting to the adverse effects of intrusive sounds and noise on children's overall mental and physical health and well-being have not received similar attention. This, despite the fact that many studies have demonstrated that intrusive noises such as those from passing road traffic, nearby rail systems, and overhead aircraft can adversely affect children's cardiovascular system, memory, language development, and learning acquisition. While some schools in the United States have received funds to abate intrusive aircraft noise, for example, many schools still expose children to noises from passing traffic and overhead aircraft. Discussion focuses on the harmful effects of noise on children, what has to be done to remedy the situation, and the need for action to lessen the impacts of noise from all sources. Furthermore, based on our knowledge of the harmful effects of noise on children's health and the growing body of evidence to suggest the potential harmful effects of industrial wind turbine noise, it is strongly urged that further studies be conducted on the impacts of industrial wind turbines on their health, as well as the health of their parents, before forging ahead in siting industrial wind turbines.

Enbom H and Enbom IM, Infrasound from wind turbines: An overlooked health hazard," Läkartidningen, vol. 110 (2013), pp. 1388-89.

Abstract:
Infrasound from wind turbines affects the inner ear and is a potential health risk for people with migraine or other type of central nervous system. The authors maintain that the legal framework for the creation of new wind turbines should be revised, taking into account this fact. Previous scientific studies on wind turbines and infrasound have been contradictory. They have therefore not been sufficiently credible when planning a framework for the establishment of wind turbines. In recent years, however, a new insight has emerged on the central nervous system, providing a better understanding of migraine, fibromyalgia and other chronic pain syndromes and some cases of tinnitus and dizziness. This understanding is also important for understanding how infrasound from wind turbines can affect health. Several studies have found that living near wind turbines often create severe sleep disturbance and depression. They have also found an increased incidence of dizziness, tinnitus, hyperacusis, headache, increased activation of the autonomic nervous system, etc.

Farboud, A.; Crunkhorn, R.; and Trinidade, A.
Wind turbine syndrome: fact or fiction? Review Article
The Journal of Laryngology & Otology, 1 of 5.

doi: 10.1017/S0022215112002964

Abstract
Objective: Symptoms, including tinnitus, ear pain and vertigo, have been reported following exposure to wind turbine noise. This review addresses the effects of infrasound and low frequency noise and questions the existence of 'wind turbine syndrome'.
Design: This review is based on a search for articles published within the last 10 years, conducted using the PubMed database and Google Scholar search engine, which included in their title or abstract the terms 'wind turbine', 'infrasound' or 'low frequency noise'.
Results: There is evidence that infrasound has a physiological effect on the ear. Until this effect is fully understood, it is impossible to conclude that wind turbine noise does not cause any of the symptoms described. However, many believe that these symptoms are related largely to the stress caused by unwanted noise exposure.
Conclusion: There is some evidence of symptoms in patients exposed to wind turbine noise. The effects of infrasound require further investigation.
There is ample evidence of symptoms arising in individuals exposed to wind turbine noise. Some researchers maintain that the effects of wind turbine syndrome are clearly just examples of the well known stress effects of exposure to noise, as displayed by a small proportion of the population. However, there is an increasing body of evidence suggesting that infrasound and low frequency noise have physiological effects on the ear. Until these effects are fully understood, it is impossible to state conclusively that exposure to wind turbine noise does not cause any of the symptoms described. The effects of infrasound and low frequency noise require further investigation.

Harrison, John P.
Wind Turbine Noise
Bulletin of Science Technology & Society 2011 31: 256, DOI: 10.1177/0270467611412549
http://bst.sagepub.com/content/31/4/256

Abstract
Following an introduction to noise and noise regulation of wind turbines, the problem of adverse health effects of turbine noise is discussed. This is attributed to the characteristics of turbine noise and deficiencies in the regulation of this noise. Both onshore and offshore wind farms are discussed.

Havas, Magda and Colling, David
Wind Turbines Make Waves:
Why Some Residents Near Wind Turbines Become Ill
Bulletin of Science Technology & Society 2011 31: 414. DOI: 0.1177/0270467611417852
http://bst.sagepub.com/content/31/5/369

Abstract
People who live near wind turbines complain of symptoms that include some combination of the following: difficulty sleeping, fatigue, depression, irritability, aggressiveness, cognitive dysfunction, chest pain/pressure, headaches, joint pain, skin irritations, nausea, dizziness, tinnitus, and stress. These symptoms have been attributed to the pressure (sound) waves that wind turbines generate in the form of noise and infrasound. However, wind turbines also generate electromagnetic waves in the form of poor power quality (dirty electricity) and ground current, and these can adversely affect those who are electrically hypersensitive. Indeed, the symptoms mentioned above are consistent with electrohypersensitivity. Sensitivity to both sound and electromagnetic waves differs among individuals and may explain why not everyone in the same home experiences similar effects. Ways to mitigate the adverse health effects of wind turbines are presented.

Hanning, Christopher D. and Evans, Alun
Editorial: Wind turbine noise
British Medical Journal, BM J2 012;344 doi: 10.1136/ bmj.e1527 (8 March 2012)
www.bmj.com

Except from BMJ web site:
Seems to affect health adversely and an independent review of evidence is needed.

The evidence for adequate sleep as a prerequisite for human health, particularly child health, is overwhelming. Governments have recently paid much attention to the effects of environmental noise on sleep duration and quality, and to how to reduce such noise. However, governments have also imposed noise from industrial wind turbines on large swathes of peaceful countryside.

The impact of road, rail, and aircraft noise on sleep and daytime functioning (sleepiness and cognitive function) is well established. Shortly after wind turbines began to be erected close to housing, complaints emerged of adverse effects on health. Sleep disturbance was the main complaint. Such reports have been dismissed as being subjective and anecdotal, but experts contend that the quantity, consistency, and ubiquity of the complaints constitute epidemiological evidence of a strong link between wind turbine noise, ill health, and disruption of sleep.

The noise emitted by a typical onshore 2.5 MW wind turbine has two main components. A dynamo mounted on an 80 m tower is driven through a gear train by …

Horner, Brett; Jeffery Roy D.; and Krogh, Carmen M. E.
Literature Reviews on Wind Turbines and Health : Are They Enough?
Bulletin of Science Technology & Society 2011 31: 399.
DOI: 10.1177/0270467611421849
http://bst.sagepub.com/content/31/5/399

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.

James, Richard R.
Wind Turbine Infra and Low-Frequency Sound: Warnings Signs That Were Not Heard
DOI: 10.1177/0270467611421845
Bulletin of Science Technology & Society published online 15 December 2011
http://bst.sagepub.com/content/early/2011/11/07/0270467611421845

Abstract
Industrial wind turbines are frequently thought of as benign. However, the literature is reporting adverse health effects associated with the implementation of industrial-scale wind developments. This article explores the historical evidence about what was known regarding infra and low-frequency sound from wind turbines and other noise sources during the period from the 1970s through the end of the 1990s. This exploration has been accomplished through references, personal interviews and communications, and other available documentation. The application of past knowledge could improve the current siting of industrial wind turbines and avoid potential risks to health.

Jeffery, Roy D.; Krogh, Carmen; and Horner, Brett
Industrial wind turbines and adverse health effects
Can J Rural Med 2014;19(1)
http://www.cma.ca/multimedia/staticContent/HTML/N0/l2/cjrm/vol-19/issue-1/pdf/pg21.pdf

Health is one of the fundamental rights of every human being. Some people exposed to IWTs experience negative effects to their physical, mental and social well-being. There is sufficient evidence to support the hypothesis of Colby and colleagues that documented symptoms can result from annoyance to audible IWTs. Amplitude modulation of IWTs, audible LFN, and tonal, impulse and nighttime noise can contribute to annoyance and other effects on health. In addition, there is emerging evidence that suggests inaudible LFN or infrasound from IWTs may result in negative health effects.

Further research is required to clarify the exact role that sound characteristics, visual impacts, stray voltage and socioeconomic impacts of IWTs may have on human health. As more IWTs are installed, rural physicians are likely to be presented with increasing numbers of patients who are adversely affected. Based on current knowledge, we expect that, at typical setback distances and sound pressure levels of IWTs in Ontario, a nontrivial percentage of exposed people will be adversely affected. "Trade-offs" of health for perceived benefit in alternate forms of energy can be prevented if setback distances and noise limits are developed using established noise management techniques. In addition to providing care for affected patients, rural physicians have a responsibility to advance understanding and to help inform IWT regulations that will protect the physical, mental and social well-being of patients.

Jeffery, Roy D.; Krogh, Carmen; and Horner, Brett
Adverse health effects of industrial wind turbines
Can Fam Physician 2013; 59: 473-475 (Commentary)
Link http://www.cfp.ca/content/59/5/473.full

Conclusion
Industrial wind turbines can harm human health if sited too close to residents. Harm can be avoided if IWTs are situated at an appropriate distance from humans. Owing to the lack of adequately protective siting guidelines, people exposed to IWTs can be expected to present to their family physicians in increasing numbers. The documented symptoms are usually stress disorder–type diseases acting via indirect pathways and can represent serious harm to human health. Family physicians are in a position to effectively recognize the ailments and provide an empathetic response. In addition, their contributions to clinical studies are urgently needed to clarify the relationship between IWT exposure and human health and to inform regulations that will protect physical, mental, and social well-being.

Jeffery, Roy D.; Krogh, Carmen; and Horner, Brett
Adverse health effects of industrial wind turbines
Can Fam Physician 2013; 59: 921-924 (Letter to the Editor)
Link http://www.cfp.ca/content/current

Conclusion
Mr Barnard writes that health effects are related to the negative attitude of the individual exposed to IWTs. Some researchers have found that the IWTs were initially welcomed into communities for their perceived economic or environmental benefits. "The reported adverse impacts were unexpected." The 2011 Ontario Real Estate Association Form 220 (Seller Property Information Statement) requires disclosure of environmental issues when selling residential property, including toxic waste, soil contamination, landfills, and wind turbines planned for the immediate area. The adverse health effects of audible and inaudible noise are substantial. Their effects are underestimated and underappreciated by some. We are guided by the references and the desire to safeguard the health and wellbeing of those living in the environs of IWTs. Harm can be avoided by placing IWTs at a protective distance from residents. The acknowledgment that health effects occur in some is an important step toward achieving this goal.

Krogh, Carmen M.E.
Industrial Wind Turbine Development and Loss of Social Justice?
Bulletin of Science Technology & Society 2011 31: 321, DOI: 10.1177/0270467611412550,
http://bst.sagepub.com/content/31/4/321

Abstract
This article explores the loss of social justice reported by individuals living in the environs of industrial wind turbines (IWTs). References indicate that some individuals residing in proximity to IWT facilities experience adverse health effects. These adverse health effects are severe enough that some families have abandoned their homes. Individuals report they welcomed IWTs into their community and the negative consequences were unexpected. Expressions of grief are exacerbated by the emotional and physical toll of individuals' symptoms, loss of enjoyment of homes and property, disturbed living conditions, financial loss, and the lack of society's recognition of their situation. The author has investigated the reported loss of social justice through a review of literature, personal interviews with, and communications from, those reporting adverse health effects. The author's intention is to create awareness that loss of social justice is being associated with IWT development. This loss of justice arises from a number of factors, including the lack of fair process, the loss of rights, and associated disempowerment. These societal themes require further investigation. Research by health professionals and social scientists is urgently needed to address the health and social impacts of IWTs operating near family homes.

Krogh, Carmen M.E.; Gillis, Lorrie; Kouwen, Nicholas; and Aramini, Jeffery
WindVOiCe, a Self-Reporting Survey: Adverse Health Effects, Industrial Wind Turbines, and the Need for Vigilance Monitoring
Bulletin of Science Technology & Society 2011 31: 334,
DOI: 10.1177/0270467611412551,
http://bst.sagepub.com/content/31/4/334

Abstract
Industrial wind turbines have been operating in many parts of the globe. Anecdotal reports of perceived adverse health effects relating to industrial wind turbines have been published in the media and on the Internet. Based on these reports, indications were that some residents perceived they were experiencing adverse health effects. The purpose of the WindVOiCe health survey was to provide vigilance monitoring for those wishing to report their perceived adverse health effects. This article discusses the results of a self reporting health survey regarding perceived adverse health effects associated with industrial wind turbines.

Möller-Levet CS; Archer SN; Bucca, G; Laing EE; Slak A; Kabiljo R; Lo JCY.; Santhi N; von Schantz M; Smith CP.; and Derk-Jan D
Effects of insufficient sleep on circadian rhythmicity and expression amplitude of the human blood transcriptome
Published online before print February 25, 2013, doi:10.1073/pnas.1217154110
PNAS (Proceedings of the National Academy of Sciences)
February 25, 2013 201217154 http://www.pnas.org/content/early/2013/02/20/1217154110

Abstract (Excerpt)
Insufficient sleep and circadian rhythm disruption are associated with negative health outcomes, including obesity, cardiovascular disease, and cognitive impairment, but the mechanisms involved remain largely unexplored. … Biological processes affected included chromatin modification, gene-expression regulation, macromolecular metabolism, and inflammatory, immune and stress responses. Thus, insufficient sleep affects the human blood transcriptome, disrupts its circadian regulation, and intensifies the effects of acute total sleep deprivation. The identified biological processes may be involved with the negative effects of sleep loss on health, and highlight the interrelatedness of sleep homeostasis, circadian rhythmicity, and metabolism.

Møller, Henrik and Pedersen, Christian Sejer
Low-frequency noise from large wind turbines
Section of Acoustics, Aalborg University, Denmark, Acoustical Society of America [DOI: 10.1121/1.3543957] J. Acoust. Soc. Am. 129 (6), June 2011 PACS number(s): 43.50.Rq, 43.28.Hr, 43.50.Cb, 43.50.Sr [ADP] Pages: 3727–3744

Abstract
As wind turbines get larger, worries have emerged that the turbine noise would move down in frequency and that the low-frequency noise would cause annoyance for the neighbors. The noise emission from 48 wind turbines with nominal electric power up to 3.6 MW is analyzed and discussed. The relative amount of low-frequency noise is higher for large turbines (2.3–3.6 MW) than for small turbines (2 MW), and the difference is statistically significant. The difference can also be expressed as a downward shift of the spectrum of approximately one-third of an octave. A further shift of similar size is suggested for future turbines in the 10-MW range. Due to the air absorption, the higher low-frequency content becomes even more pronounced, when sound pressure levels in relevant neighbor distances are considered. Even when A-weighted levels are considered, a substantial part of the noise is at low frequencies, and for several of the investigated large turbines, the one-third-octave band with the highest level is at or below 250 Hz. It is thus beyond any doubt that the low-frequency part of the spectrum plays an important role in the noise at the neighbors.

McMurtry, Robert Y.
Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis
Bulletin of Science Technology & Society 2011 31: 316, DOI: 10.1177/0270467611415075,
http://bst.sagepub.com/content/31/4/316

Abstract
Internationally, there are reports of adverse health effects (AHE) in the environs of industrial wind turbines (IWT). There was multidisciplinary confirmation of the key characteristics of the AHE at the first international symposium on AHE/IWT. The symptoms being reported are consistent internationally and are characterized by crossover findings or a predictable appearance of signs and symptoms present with exposure to IWT sound energy and amelioration when the exposure ceases. There is also a revealed preference of victims to seek restoration away from their homes. This article identifies the need to create a case definition to establish a clinical diagnosis. A case definition is proposed that identifies the sine qua non diagnostic criteria for a diagnosis of adverse health effects in the environs of industrial wind turbines. Possible, probable, and confirmed diagnoses are detailed. The goal is to foster the adoption of a common case definition that will facilitate future research efforts.

Munzel T, Goril T, Babisch W, Basner M, Cardiovascular effects of environmental noise exposure
European Heart Journal (2014) 35, 829–836
doi: 10.1093/eurheartj/ehu030

Summary
The role of noise as an environmental pollutant and its impact on health are being increasingly recognized. Beyond its effects on the auditory system, noise causes annoyance and disturbs sleep, and it impairs cognitive performance. Furthermore, evidence from epidemiologic studies demonstrates that environmental noise is associated with an increased incidence of arterial hypertension, myocardial infarction, and stroke. Both observational and experimental studies indicate that in particular night-time noise can cause disruptions of sleep structure, vegetative arousals (e.g. increases of blood pressure and heart rate) and increases in stress hormone levels and oxidative stress, which in turn may result in endothelial dysfunction and arterial hypertension. This review focuses on the cardiovascular consequences of environmental noise exposure and stresses the importance of noise mitigation strategies for public health.

Conclusions
Taken together, the present review provides evidence that noise not only causes annoyance, sleep disturbance, or reductions in quality of life, but also contributes to a higher prevalence of the most important cardiovascular risk factor arterial hypertension and the incidence of cardiovascular diseases. The evidence supporting such contention is based on an established rationale supported by experimental laboratory and observational field studies, and a number of epidemiological studies. Meta-analyses have been carried out to derive exposure–response relationships that can be used for quantitative health impact assessments. Noise-induced sleep disturbance constitutes an important mechanism on the pathway from chronic noise exposure to the development of adverse health effects. The results call for more initiatives aimed at reducing environmental noise exposure levels to promote cardiovascular and public health. Recent studies indicate that people's attitude and awareness in particular towards aircraft noise has changed over the years. Noise mitigation policies have to

consider the medical implications of environmental noise exposure. Noise mitigation strategies to improve public health include noise reduction at the source, active noise control (e.g. noise optimized take-off and approach procedures), optimized traffic operations (including traffic curfews), better infrastructural planning, better sound insulation in situations where other options are not feasible, and adequate limit values.

Nissenbaum, Michael A.; Aramini, Jeffery J.; and Hanning, Christopher D.
Effects of industrial wind turbine noise on sleep and health
Noise & Health, September-October 2012, Volume 14, p243
www.noiseandhealth.org

Abstract
Industrial wind turbines (IWTs) are a new source of noise in previously quiet rural environments. Environmental noise is a public health concern, of which sleep disruption is a major factor. To compare sleep and general health outcomes between participants living close to IWTs and those living further away from them, participants living between 375 and 1400 m (n = 38) and 3.3 and 6.6 km (n = 41) from IWTs were enrolled in a stratified cross-sectional study involving two rural sites. Validated questionnaires were used to collect information on sleep quality (Pittsburgh Sleep Quality Index — PSQI), daytime sleepiness (Epworth Sleepiness Score — ESS), and general health (SF36v2), together with psychiatric disorders, attitude, and demographics. Descriptive and multivariate analyses were performed to investigate the effect of the main exposure variable of interest (distance to the nearest IWT) on various health outcome measures. Participants living within 1.4 km of an IWT had worse sleep, were sleepier during the day, and had worse SF36 Mental Component Scores compared to those living further than 1.4 km away. Significant dose-response relationships between PSQI, ESS, SF36 Mental Component Score, and log-distance to the nearest IWT were identified after controlling for gender, age, and household clustering. The adverse event reports of sleep disturbance and ill health by those living close to IWTs are supported.

Persinger, Michael A.
Infrasound, human health, and adaptation:
an integrative overview of recondite hazards in a complex environment
Nat Hazards
DOI 10.1007/s11069-013-0827-3
This article is published with open access at www.Springerlink.com

Conclusion

Living systems, including the human species, have evolved within a natural environment whose properties are complex but not intractable to measurement and understanding. Although the partitioning of the formal description of natural phenomena by different scientific disciplines may have satisfied the conditions of human cognition, the subsequent traditions may have obscured the essential relationships between human adaptation and the natural environment that is optimally discerned through true interdisciplinary approaches.

Human beings can be described as both mechanical and energetic organisms. There are multiple sources of stimuli that exhibit energetic equivalents whose values in turn converge with those essential for the function of the cell, the organ, and the organism. The frequencies that have been defined as infrasound, from natural, manufactured, and as yet unknown sources, have the capacity to resonate with the human body. This review of the scientific literature and the quantitative illustrations derived from the systematic application of known principles may facilitate the acquisition

of the precision required to differentiate between natural hazards and natural benefits rather than depending primarily upon political and social agendas.

Phillips, Carl V.
Properly Interpreting the Epidemiologic Evidence About the Health Effects of Industrial Wind Turbines on Nearby Residents
Bulletin of Science Technology & Society 2011 31: 303, DOI: 10.1177/0270467611412554,
http://bst.sagepub.com/content/31/4/303

Abstract
There is overwhelming evidence that wind turbines cause serious health problems in nearby residents, usually stress-disorder type diseases, at a nontrivial rate. The bulk of the evidence takes the form of thousands of adverse event reports. There is also a small amount of systematically gathered data. The adverse event reports provide compelling evidence of the seriousness of the problems and of causation in this case because of their volume, the ease of observing exposure and outcome incidence, and case-crossover data. Proponents of turbines have sought to deny these problems by making a collection of contradictory claims including that the evidence does not "count," the outcomes are not "real" diseases, the outcomes are the victims' own fault, and that acoustical models cannot explain why there are health problems so the problems must not exist. These claims appeared to have swayed many nonexpert observers, though they are easily debunked. Moreover, though the failure of models to explain the observed problems does not deny the problems, it does mean that we do not know what, other than kilometers of distance, could sufficiently mitigate the effects. There has been no policy analysis that justifies imposing these effects on local residents. The attempts to deny the evidence cannot be seen as honest scientific disagreement and represent either gross incompetence or intentional bias.

Punch, Jerry; James, Rick; and Pabst, Dan
Wind-Turbine Noise
What Audiologists Should Know
Audiology Today, July/August 2010

Conclusion
Our purpose in this article has been to provide audiologists with a better understanding of the types of noise generated by wind turbines, some basic considerations underlying sound-level measurements of wind-turbine noise, and the adverse health effects on people who live near these turbines. In future years, we expect that audiologists will be called upon to make noise measurements in communities that have acquired wind turbines, or are considering them. Some of us, along with members of the medical profession, will be asked to provide legal testimony regarding our opinions on the effects of such noise on people. Many of us will likely see clinical patients who are experiencing some of the adverse health effects described in this article. As a professional community, audiologists should become involved not only in making these measurements to corroborate the complaints of residents living near wind-turbine projects but also in developing and shaping siting guidelines that minimize the potentially adverse health effects of the noise and vibration they generate. In these ways, we can promote public health interests without opposing the use of wind turbines as a desirable and viable alternative energy source.

Rand, Robert W.; Ambrose, Stephen E.; and Krogh, Carmen M. E.
Occupational Health and Industrial Wind Turbines: A Case Study
Bulletin of Science Technology & Society 2011 31: 359 DOI: 10.1177/0270467611417849
http://bst.sagepub.com/content/31/5/359

Abstract
Industrial wind turbines (IWTs) are being installed at a fast pace globally. Researchers, medical practitioners, and media have reported adverse health effects resulting from living in the environs of IWTs. While there have been some anecdotal reports from technicians and other workers who work in the environs of IWTs, little is known about the occupational health sector. The purpose of this case study is to raise awareness about the potential for adverse health effects occurring among workers. The authors propose that there is a need for research regarding occupational worker exposure relating to IWTs.

Salt, Alec N. and Hullar, T.E.
Responses of the ear to low frequency sounds, infrasound and wind turbines.
Department of Otolaryngology, Washington University School of Medicine, St. Louis, MO, 63110, USA.
Hearing Research 2010 Sep 1; 268(1-2):12-21. Epub 2010 Jun 16

Abstract
Infrasonic sounds are generated internally in the body (by respiration, heartbeat, coughing, etc) and by external sources, such as air conditioning systems, inside vehicles, some industrial processes and, now becoming increasingly prevalent, wind turbines. It is widely assumed that infrasound presented at an amplitude below what is audible has no influence on the ear. In this review, we consider possible ways that low frequency sounds, at levels that may or may not be heard, could influence the function of the ear. The inner ear has elaborate mechanisms to attenuate low frequency sound components before they are transmitted to the brain. The auditory portion of the ear, the cochlea, has two types of sensory cells, inner hair cells (IHC) and outer hair cells (OHC), of which the IHC are coupled to the afferent fibers that transmit "hearing" to the brain. The sensory stereocilia ("hairs") on the IHC are "fluid coupled" to mechanical stimuli, so their responses depend on stimulus velocity and their sensitivity decreases as sound frequency is lowered. In contrast, the OHC are directly coupled to mechanical stimuli, so their input remains greater than for IHC at low frequencies. At very low frequencies the OHC are stimulated by sounds at levels below those that are heard. Although the hair cells in other sensory structures such as the saccule may be tuned to infrasonic frequencies, auditory stimulus coupling to these structures is inefficient so that they are unlikely to be influenced by airborne infrasound. Structures that are involved in endolymph volume regulation are also known to be influenced by infrasound, but their sensitivity is also thought to be low. There are, however, abnormal states in which the ear becomes hypersensitive to infrasound. In most cases, the inner ear's responses to infrasound can be considered normal, but they could be associated with unfamiliar sensations or subtle changes in physiology. This raises the possibility that exposure to the infrasound component of wind turbine noise could influence the physiology of the ear.

Salt, Alec N. and Kaltenbach, James A.
Infrasound From Wind Turbines Could Affect Humans
Bulletin of Science Technology & Society 2011 31: 296,
DOI: 10.1177/0270467611412555
http://bst.sagepub.com/content/31/4/296

Abstract
Wind turbines generate low-frequency sounds that affect the ear. The ear is superficially similar to a microphone, converting mechanical sound waves into electrical signals, but does this by complex physiologic processes. Serious misconceptions about low-frequency sound and the ear have resulted from a failure to consider in detail how the ear works. Although the cells that provide hearing are insensitive to infrasound, other sensory cells in the ear are much more sensitive, which can be demonstrated by electrical recordings. Responses to infrasound reach the brain through pathways that do not involve conscious hearing but instead may produce sensations of fullness, pressure or tinnitus, or have no sensation. Activation of subconscious pathways by infrasound could disturb sleep. Based on our current knowledge of how the ear works, it is quite possible that low-frequency sounds at the levels generated by wind turbines could affect those living nearby.

Seltenrich, Nate
Wind Turbines A Different Breed of Noise?
Environmental Health Perspectives, volume 122 | number 1 | January 2014

Looking Long Term
The gold standard for proving causality of an exposure is the randomized clinical trial. But when it comes to testing the health effects of noise exposure on humans, such a study design is likely to be not only impractical and difficult to implement, but also unethical.

The next-best evidence would come from longitudinal field research, many researchers agree, such as long-term studies that assess the health of a community before a turbine project is ever proposed and then continue to follow up during operation. Lercher notes that some effects of chronic noise exposure such as elevated blood pressure could take one or two decades to manifest at significant levels.

Most of the studies performed to date around both transportation and wind-farm sources have been cross-sectional, which makes it impossible to assess causality. That's because investigators cannot establish whether the potential cause precedes the potential effect. Lercher stresses that cross-sectional studies purporting to demonstrate a relationship between noise exposures and health effects may be averaging out potential effects that are only visible in some subgroups—e.g., those with certain medical risk factors, or those exposed to the noise for longer than others.

Shain, Martin
Public Health Ethics, Legitimacy, and the Challenges of Industrial Wind Turbines: The Case of Ontario, CanadaBulletin of Science Technology & Society, 2011 31: 256
DOI: 10.1177/0270467611412552,
http://bst.sagepub.com/content/31/4/346

Abstract
While industrial wind turbines (IWTs) clearly raise issues concerning threats to the health of a few in contrast to claimed health benefits to many, the trade-off has not been fully considered in a public health framework. This article reviews public health ethics justifications for the licensing and installation of IWTs. It concludes that the current methods used by government to evaluate licensing applications for IWTs do not meet most public health ethical criteria. Furthermore, these methods are contrary to widely held fundamental principles of administrative law and governmental legitimacy. A set of decision-making principles are suggested to address this situation that are derived from existing and emerging legal principles in Canada and elsewhere. These include the Precautionary Principle, the Least Impactful Means (Proportionality) Test, and the Neighbor Principle.

Shepherd, Daniel; Welch, David; Dirks, Kim N.; and McBride, David (March 2013)
Do Quiet Areas Afford Greater Health-Related Quality of Life than Noisy Areas? International Journal of Environmental Research and Public Health, ISSN 1660-4601
http://www.mdpi.com/1660-4601/10/4/1284

Abstract: People typically choose to live in quiet areas in order to safeguard their health and wellbeing. However, the benefits of living in quiet areas are relatively understudied compared to the burdens associated with living in noisy areas. Additionally, research is increasingly focusing on the relationship between the human response to noise and measures of health and wellbeing, complementing traditional dose-response approaches, and further elucidating the impact of noise and health by incorporating human factors as mediators and moderators. To further explore the benefits of living in quiet areas, we compared the results of health-related quality of life (HRQOL) questionnaire datasets collected from households in localities differentiated by their soundscapes and population density: noisy city, quiet city, quiet rural, and noisy rural. The dose-response relationships between noise annoyance and HRQOL measures indicated an inverse relationship between the two. Additionally, quiet areas were found to have higher mean HRQOL domain scores than noisy areas. This research further supports the protection of quiet locales and ongoing noise abatement in noisy areas.

Shepherd D, Hanning C, Thorne B. Noise: Windfarms (2012) Published in the Encyclopedia of Environmental Management (peer review panel for all articles)
DOI: 10.1081/E-EEM-120047802

Abstract:
Windfarms consist of clusters of wind turbines, which, when placed in populated areas, are associated with intrusive and unwanted sound. A relatively new noise source; wind turbine noise has characteristics sufficiently different from other, more extensively studied, noise sources to suggest that preexisting noise standards are not appropriate. Though research into the human impacts of wind turbine noise has appeared only in the last decade and in small quantity, the data suggest that, for equivalent exposures, wind turbine noise is more annoying than road or aviation noise. Furthermore, the particular characteristics of wind turbine noise may be likely to cause sleep disruption. As with other impulsive noise sources, time-aggregated noise metrics have limited utility in protecting public health, and a cluster of metrics should be used in order to estimate potential threat. At this time, however, the quantity and quality of research are insufficient to effectively describe the relationship between wind turbine noise and health, and so legislation should apply the precautionary principle or conservative criteria when assessing proposed windfarm developments.

Shepherd, Daniel and Billington, Rex
Mitigating the Acoustic Impacts of Modern Technologies: Acoustic, Health, and Psychosocial Factors Informing Wind Farm Placement
Bulletin of Science Technology & Society 2011 31: 389
DOI: 10.1177/0270467611417841
http://bst.sagepub.com/content/31/5/389

Abstract
Wind turbine noise is annoying and has been linked to increased levels of psychological distress, stress, difficulty falling asleep and sleep interruption. For these reasons, there is a need for competently designed noise standards to safeguard community health and well-being. The authors

identify key considerations for the development of wind turbine noise standards, which emphasize a more social and humanistic approach to the assessment of new energy technologies in society.

Shepherd, Daniel; McBride, David; Welch; Dirks, Kim N.; and Hill Erin M.
Evaluating the impact of wind turbine noise on health related quality of life
Noise & Health, September-October 2011, 13:54,333-9
DOI: 10.4103/1463-1741.85502
www.noiseandhealth.org

Abstract
We report a cross-sectional study comparing the health-related quality of life (HRQOL) of individuals residing in the proximity of a wind farm to those residing in a demographically matched area sufficiently displaced from wind turbines. The study employed a nonequivalent comparison group posttest-only design. Self-administered questionnaires, which included the brief version of the World Health Organization quality of life scale, were delivered to residents in two adjacent areas in semirural New Zealand. Participants were also asked to identify annoying noises, indicate their degree of noise sensitivity, and rate amenity. Statistically significant differences were noted in some HRQOL domain scores, with residents living within 2 km of a turbine installation reporting lower overall quality of life, physical quality of life, and environmental quality of life. Those exposed to turbine noise also reported significantly lower sleep quality, and rated their environment as less restful. Our data suggest that wind farm noise can negatively impact facets of HRQOL.

Acknowledgements: We are grateful to our colleagues and others whose reviews substantially improved the manuscript. We are especially grateful for the thorough review undertaken by Professor Rex Billington, who as the WHO Director of Mental Health in the 1990s oversaw the development of the WHO's program into quality of life, health and the environment.

Thorne R, and Shepherd D, Quiet as an Environmental Value: A Contrast between Two Legislative Approaches. Int. J. Environ. Res. Public Health 2013, 10

Abstract
This paper examines the concept of "quiet" as an "environmental value" in terms of amenity and wellbeing from a legislative context. Critical review of two pieces of environmental legislation from Australia and New Zealand forms the basis of the paper. The Australian legislation is Queensland's Environmental Protection Act, and the New Zealand legislation is that nation's Resource Management Act. Quiet is part of the psychoacoustic continuum between a tranquil and an intrusively noisy sound environment. As such, quiet possesses intrinsic value in terms of overall sound within the environment (soundscape) and to individuals and communities. In both pieces of legislation, guidance, either directly or indirectly, is given to "maximum" sound levels to describe the acoustic environment. Only in Queensland is wellbeing and amenity described as environmental values, while in the New Zealand approach, amenity is identified as the core value to defend, but guidance is not well established. Wellbeing can be related to degrees of quietness and the absence of intrusive noise, the character of sound within an environment ("soundscape"), as well as the overall level of sound. The quality of life experienced by individuals is related to that person's physical and mental health, sense of amenity and wellbeing. These characteristics can be described in terms of subjective and objective measures, though legislation does not always acknowledge the subjective.

Thorne, Bob
The Problems With "Noise Numbers" for Wind Farm Noise Assessment
Bulletin of Science Technology & Society 2011 31: 262
DOI: 10.1177/0270467611412557,
http://bst.sagepub.com/content/31/4/262

Abstract
Human perception responds primarily to sound character rather than sound level. Wind farms are unique sound sources and exhibit special audible and inaudible characteristics that can be described as modulating sound or as atonal complex. Wind farm compliance measures based on a specified noise number alone will fail to address problems with noise nuisance. The character of wind farm sound, noise emissions from wind farms, noise prediction at residences, and systemic failures in assessment processes are examined. Human perception of wind farm sound is compared with noise assessment measures and complaint histories. The adverse effects on health of persons susceptible to noise from wind farms are examined and a hypothesis, the concept of heightened noise zones (pressure variations), as a marker for cause and effect is advanced. A sound level of LAeq 32 dB outside a residence and above an individual's threshold of hearing inside the home are identified as markers for serious adverse health effects affecting susceptible individuals. The article is referenced to the author's research, measurements, and observations at different wind farms in New Zealand and Victoria, Australia.

OTHER:

Salt AN and Lichtenhan JT, How Does Wind Turbine Noise Affect People? Acoustics Today. A publication of the Acoustical Society of America.
Volume 10: Issue One: Winter 2014

Conclusions and Concerns
We have described multiple ways in which infrasound and low-frequency sounds could affect the ear and give rise to the symptoms that some people living near wind turbines report. If, in time, the symptoms of those living near the turbines are demonstrated to have a physiological basis, it will become apparent that the years of assertions from the wind industry's acousticians that "what you can't hear can't affect you" or that symptoms are psychosomatic or a nocebo effect was a great injustice. The current highly-polarized situation has arisen because our understanding of the consequences of long-term infrasound stimulation remains at a very primitive level. Based on well-established principles of the physiology of the ear and how it responds to very low-frequency sounds, there is ample justification to take this problem more seriously than it has been to date. There are many important scientific issues that can only be resolved through careful and objective research. Although infrasound generation in the laboratory is technically difficult, some research groups are already in the process of designing the required equipment to perform controlled experiments in humans.

One area of concern is the role that some acousticians and societies of acousticians have played. The primary role of acousticians should be to protect and serve society from negative influences of noise exposure. In the case of wind turbine noise, it appears that many have been failing in that role. For years, they have sheltered behind the mantra, now shown to be false, that has been presented repeatedly in many forms such as "What you can't hear, can't affect you."; "If you cannot hear a sound you cannot perceive it in other ways and it does not affect you."; "Infrasound from wind

turbines is below the audible threshold and of no consequence."; "Infrasound is negligible from this type of turbine."; "I can state categorically that there is no significant infrasound from current designs of wind turbines." All of these statements assume that hearing, derived from low-frequency-insensitive IHC responses, is the only mechanism by which low frequency sound can affect the body. We know this assumption is false and blame its origin on a lack of detailed understanding of the physiology of the ear.

Another concern that must be dealt with is the development of wind turbine noise measurements that have clinical relevance. The use of A-weighting must be reassessed as it is based on insensitive, IHC-mediated hearing and grossly misrepresents inner ear stimulation generated by the noise. In the scientific domain, A-weighting sound measurements would be unacceptable when many elements of the ear exhibit a higher sensitivity than hearing. The wind industry should be held to the same high standards. Full-spectrum monitoring, which has been adopted in some reports, is essential.

In the coming years, as we experiment to better understand the effects of prolonged low-frequency sound on humans, it will be possible to reassess the roles played by acousticians and professional groups who partner with the wind industry. Given the present evidence, it seems risky at best to continue the current gamble that infrasound stimulation of the ear stays confined to the ear and has no other effects on the body. For this to be true, all the mechanisms we have outlined (low frequency-induced amplitude modulation, low frequency sound-induced endolymph volume changes, infrasound stimulation of type II afferent nerves, infrasound exacerbation of noise-induced damage and direct infrasound stimulation of vestibular organs) would have to be insignificant. We know this is highly unlikely and we anticipate novel findings in the coming years that will influence the debate.

From our perspective, based on our knowledge of the physiology of the ear, we agree with the insight of Nancy Timmerman that the time has come to "acknowledge the problem and work to eliminate it".

Editor: Bob Thorne,
Noise Measurement Services Pty Ltd Wind Farm Noise Review April 2013

PREAMBLE
There is significant body of peer-reviewed research readily available in the public forum to substantiate the potential for serious to moderate adverse health effects to individuals due to wind farm activity noise while living in their residences and while working on their farms near large-scale wind farms or large turbines. Adverse health effects can arise from extreme psychological stress from environmental noise, particularly low frequency noise with symptoms of sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic attack episodes associated with such sensations when awake or asleep.

The hypothesis from this Review is that serious harm to health occurs when a susceptible individual is so beset by the noise in question that he or she suffers recurring sleep disturbance, anxiety and stress.

Research for the Review suggests that 5% to 10% of the individuals living in the vicinity of a large wind farm will experience serious harm to their health. The observed markers for serious health effects are

(a) wind farm noise level of LAeq 32 dB or more outside the residence and

(b) wind farm noise is heard or is perceptible (felt) at levels above the individual's threshold of hearing inside the home

Meteorological conditions, wind turbine spacing and associated wake and turbulence effects, vortex effects, wind shear, turbine synchronicity, tower height, blade length, and power settings all contribute to sound levels heard or perceived at residences. Wind farms are unique sound sources and exhibit special audible characteristics that can be described as modulating sound or as a tonal complex. Current noise prediction models are simplistic, have a high degree of uncertainty, and do not make allowance for these significant variables. Compliance monitoring must therefore include continuous real-time measurement of characteristics such as modulating sound in order to determine the perceptible effects of audible sound and inaudible infrasound.

The Review contains references to the NMS research, measurements, and observations at different wind farms in New Zealand and Australia. All NMS research including the study methodologies are peer reviewed. Such work is commercial-in-confdence to NMS and of a confidential nature to the participants. No datasets, apart from those presented in this Review, are disclosed or publicly available.

CONFERENCE PAPERS

Ambrose, Stephen E.; Rand, Robert W.; and Krogh, Carmen M. E.
Falmouth, Massachusetts wind turbine infrasound and low frequency noise measurements
Invited paper presented at Inter-noise 2012 New York City, NY

Abstract
Falmouth, Massachusetts has experienced non-predicted adverse acoustic and health impacts from an industrial wind turbine (IWT) sited close to neighbors. The public response from this quiet rural area has been very vocal for a majority of homeowners living within 3000-ft. Complaints have ranged from the unexpectedly loud with constant fluctuations and the non-audible pressure fluctuations causing a real loss of public health and well-being. Early research indicates that both the IHC and OHC functions of the ear receive stimulation during moderate to strong wind speeds. This research presents a challenge to noise control and health professionals to determine the causal factors for the adverse public health impacts. This case study will present sound level and analyzed measurement data obtained while living in a house 1700-ft from an operating IWT during moderate to strong hub height wind speeds. There was a strong correlation with wind speed, power output and health symptoms.

Andreucci, Federica; Atzori, Delio; Baratta, Claudio; Betti, Rinaldo; Carriero, Antonella et al.
Correlation between people perception of noise from large wind turbines and measured noise levels
Paper presented at the Wind Turbine Noise conference 2013, August 28 to 30, Denver, Colorado, USA

Summary
ISPRA, in collaboration with the Sapienza University of Rome, have carried out a study on perceptions, opinions and attitudes of citizens in relation to the planning, implementation and working of wind power systems. The study area has involved four municipalities in the South of Italy, including the municipality of Sant'Agata di Puglia (Foggia). The research activities have been divided in two main phases: a first phase of empirical research based on interviews, and the second

phase of survey by means questionnaire distribution to a sample citizens in the above mentioned municipalities.

In particular, questionnaires have been distributed to sample citizens of Sant'Agata di Puglia at the aims to acquire piece of information on people perception of noise produced by working wind power systems. Moreover, in order to correlate the qualitative judgments resulting from this survey with the real noise impact in the interested areas, a noise measurement campaign has been carried out at two dwellings considered significant in terms of noise level exposure.

Conclusions
The analysis of the data recorded at the two receivers during the monitoring campaign in October-November 2012, has shown an overall environmental noise levels characterized by a low average noise levels, even lower than those provided by environmental legislation.
In the other hand, we have to also consider the comments and the noise perceptual assessment of the population emerged by the ISPRA sociological study.

In fact, this study reports that in cases of stratification of the population particularly exposed to wind farm, in the municipalities of Sant'Agata di Puglia and Orsara, there are cases of complaints and sensitivity to the noise produced by working wind farms that, as said above, probably can be attributed to the annoy relate to the periodical-frequency of the sound signal linked to the rotation of wind turbine blades, rather than the produced environmental overall sound pressure levels.

Bray, Wade
Relevance and applicability of the Soundscape concept to physiological or behavioural effects caused by noise at very low frequencies which may not be audible
Acoustical Society of America 164th Meeting, Kansas City, MO 22 - 26 October, 2012, 2aNS6

Abstract:
A central tenet of the Soundscape concept is that humans immersed in sonic environments are objective measuring instruments (New Experts), whose reports and descriptions must be taken seriously and quantified by technical measurements. A topic category in acoustics meetings of recent years is "Perception and Effects of Noise." There is growing evidence from the field, and from medical research, that the ear's two - part transducer activity involving inner hair cells (IHC, hearing, velocity sensitive) and outer hair cells (OHC, displacement - sensitive) may, through demonstrated OHC activation and neural signals at up to 40 dB below the audibility threshold, produce behavioral and physiological effects as reported by a growing number of people. The Soundscape concept centering on human responses, New Experts, is as important and applicable to responses to effects from sound as it is to responses to directly audible sound. In a wider sense, this is a new sound quality and psychoacoustic issue.

Cole, Peter N. MD, MHSc, FRCP(C) and Krogh, Carmen, BScPharm
Wind Turbine Facilities' Perception: A Case Study from Canada
5th International Conference on Wind Turbine Noise Denver 28 – 30 August 2013 (published in proceedings but not presented)

Summary:
This paper is a family case study looking at the adverse health effects of living in close proximity to wind turbines and transformers. It reviews the wind farm project, complaints of the family and their neighbours, and the results of testing by private and official agencies for low frequency noise (LFN), electromagnetic fields and electrical phenomena associated with wind turbines and transformers. It

also looks at the impact of perceived self-efficacy on health. The findings and conclusions point to LFN and perceived self-efficacy as the most likely causes of the family's complaints.

Horner, Brett; Krogh, Carmen ME; and Jeffery, Roy D.
Audit report: literature reviews on wind turbine noise and health
Paper presented at the Wind Turbine Noise conference 2013, August 28 to 30, Denver, Colorado, USA

Abstract
Wind turbines can harm humans if placed too close to residents. Health effects are most frequently associated with wind turbine noise. At typical setbacks and sound levels in Ontario Canada 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. In recent years a number of literature reviews have been produced which purport to examine the plausibility of wind turbine noise induced health effects. Some of these literature reviews have been sponsored by governments or organizations with policies which support wind energy development. Members of and/or consultants for the wind energy industry frequently cite literature reviews to support the claim wind turbine noise does not pose a risk to human health. Various literature reviews on wind turbines and health are examined using standard audit procedures. Findings reveal that while some literature reviews provide a balanced assessment other literature reviews contain errors of omission and/or commission and lack completeness, accuracy, and objectivity. These findings support the conclusion that a rigorous audit should be conducted before literature reviews on wind turbine noise and health can be relied upon.

Krogh, Carmen ME; Morris, Joan; May, Murray; Papadopoulos, George; and Horner, Brett
Trading off human health: Wind turbine noise and government policy
Paper presented at the Wind Turbine Noise conference 2013, August 28 to 30, Denver, Colorado, USA

Abstract
Noise is considered a threat to public health that can seriously harm humans. Understanding the health impacts of noise has advanced significantly over past decades. Some jurisdictions responded by implementing policies to reduce the negative health effects of transportation and industrial noise. These gains in health protection from noise are under threat. In Canada government policies to support wind energy development have been adopted, in part, to reduce dependency on fossil fuels. However, wind energy facilities can produce unwanted sound and negative health and social economic effects when sited too close to humans. Peer reviewed literature, case reports, and access to information documents are used to evaluate government policies in Canada. Together these sources support the conclusion that human health is being traded off in favour of government policies that support wind energy development. This trade off conflicts with international charters that acknowledge the highest attainable standard of health is a fundamental right of every human being.

Krogh, Carmen ME; Jeffery, Roy D; Aramini, Jeff; and Horner, Brett
Wind turbines can harm humans: a case study
Paper presented at Inter-noise 2012, New York City, NY

Abstract
In Canada the Ontario Government has adopted wind energy as a renewable energy source. Our research in Ontario 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 economic impacts. Some families have abandoned their homes or

negotiated financial agreements with wind energy developers. Wind turbine noise is a reported cause of these effects; however, some commentators suggest sound from wind turbines does not pose a risk of any adverse health effect in humans. These competing claims can confuse authorities responsible for establishing noise guidelines. 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. Risks must be understood to ensure guidelines protect human health. Evidence including peer reviewed literature, case reports, freedom of information documents and expert testimony will be presented which support the conclusion that wind turbines, if placed too close to residents, can harm human health.

Krogh, Carmen ME; Jeffery, Roy D; Aramini, Jeff; and Horner, Brett
Wind turbine noise perception, pathways and effects: a case study
Paper presented at Inter-noise 2012, New York City, NY

Abstract

In Ontario Canada wind turbines are being sited close to humans. Wind turbine noise is perceived to be more annoying than other equally loud sources of sound. This annoyance can contribute to stress related health impacts. An Ontario government commissioned report concludes a nontrivial percentage of exposed persons will be impacted. Our research documents some Ontarians living in the environs of wind turbines report experiencing physiological and psychological symptoms, reduced quality of life, degraded living conditions, and adverse social economic impacts including a loss of social justice. In some cases the effects resulted in families abandoning their homes. Others have negotiated financial agreements with wind energy developers. An Ontario Environmental Tribunal considered a wide body of evidence including expert witness testimony and found that wind turbines can harm humans if placed too close to residents. Peer reviewed literature, case reports, freedom of information documents and expert testimony will be presented which support the conclusion that noise perception via the indirect pathway can result in serious negative effects.

Krogh, Carmen ME; Jeffery, Roy D; Aramini, Jeff; and Horner, Brett
Annoyance can represent a serious degradation of health:
wind turbine noise a case study
Paper presented at Inter-noise 2012, New York City, NY

Abstract

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

Salt, Alec N. and Lichtenhan, Jeffery T.
Responses of the Inner Ear to Infrasound
Fourth International Meeting on Wind Turbine Noise
Rome, Italy, 12-14 April 2011

Abstract:
Unweighted sound measurements show that wind turbines generate high levels of infrasound. It has been wrongly assumed that if subjects cannot hear the infrasound component of the noise then they cannot be affected by it. On the contrary, the mammalian ear is highly sensitive to infrasound stimulation at levels below those that are heard. Most aspects of responses to infrasound are far from well established. Measurements made within the endolymphatic system of the cochlea show responses that become larger, relative to measurements made in perilymph, as frequency is lowered. This suggests that endolymphatic responses to infrasound are enhances in some manner. For high-frequency sound, acoustic stimuli in the ear are summed. In contrast, the inner ear's responses to infrasound are suppressed by the presence of higher frequency stimuli. The complexity of the ear's response to infrasound leads us to the conclusion that there are many aspects that need to be better understood before the influence of wind turbine noise on the ear can be dismissed as insignificant.

Salt, Alec N. and Lichtenhan, Jeffery T.
Perception-based protection from low-frequency sounds may not be enough
Invited paper presented at Inter-noise 2012, New York City, NY

Acknowledgements
This work was supported by grant R01 DC001368 from the NIDCD, National Institutes of Health. We thank Jared Hartsock and Ruth Gill for their assistance with the experiments.

Abstract
Hearing and perception in the mammalian ear are mediated by the inner hair cells (IHC). IHCs are fluid-coupled to mechanical vibrations and have been characterized as velocity sensitive, making them quite insensitive to low-frequency sounds. But the ear also contains more numerous outer hair cells (OHC), which are not fluid coupled and are characterized as displacement sensitive. The OHCs are more sensitive than IHCs to low frequencies and respond to very low-frequency sounds at levels below those that are perceived. OHC are connected to the brain by type II afferent fibers to networks that may further attenuate perception of low frequencies. These same pathways are also involved in alerting and phantom sounds (tinnitus). Because of these anatomic configurations, low-frequency sounds that are not perceived may cause influence in ways that have not yet been adequately studied. We present data showing that the ear's response to low-frequency sounds is influenced by the presence of higher-frequency sounds such as those in the speech frequency range, with substantially larger responses generated when higher-frequency components are absent. We conclude that the physiological effects of low-frequency sounds are more complex than is widely appreciated. Based on this knowledge, we have to be concerned that sounds that are not perceived are clearly transduced by the ear and may still affect people in ways that have yet to be fully understood.

Schomer, Paul
Can wind turbine sound that is below the threshold of hearing be heard?
2013 Acoustical Society of America [DOI: 10.1121/1.4801065]
Proceedings of Meetings on Acoustics, Vol. 19, 040063 (2013)

This paper is geared towards wind turbine sound, but it is really a simple variation on the basic concepts that this author used in the development of loudness-level-weighted sound exposure (Schomer et al., J. Acoust. Soc. Am, 110(5), Pt. 1, 2390-2397, 2001) and of Rating Noise Curves (RNC) (Schomer, Noise Cont. Eng. J., 48(3), 85-96, 2000), which are used in the Standard, ANSI/ASA S12.2 Criteria for evaluating room noise. The fundamental issue is: Can we hear slowly

surging or pulsating sounds for which the LEQ spectrum is below the threshold of hearing, where "slowly" means that the pulses come at a rate that is no faster than about 4 pulses per second? The short answer is yes, and the longer answer is that this effect is a function of the spectral content and becomes more-and-more prominent as the spectral content goes lower-and-lower in the audible frequency range. So surging or pulsing sound that is primarily in the 16 or 31 Hz octave bands will show the greatest effect. This paper shows the applicability of these results to wind-turbine sound.

Shepherd, Daniel;, McBride, David; Welch, David; Dirks, Kim; Hill, Erin.
Wind turbine noise and health-related quality of life of nearby residents: a cross sectional study in New Zealand
Presented at the Fourth International Meeting on Wind Turbine Noise, Rome, 2011
http://otago.ourarchive.ac.nz/handle/10523/2260 24/03/2013

Abstract:
Hearing allows humans to detect threats in the environment and to communicate with others. However, unwanted sound has the capacity to evoke reflexive and emotional responses, and can act a stressor. The World Health Organisation classifies noise as an environmental pollutant that degrades sleep, quality of life and general health. Previous research provides evidence of a relationship between wind turbine noise and both annoyance and sleep disturbance. However, wind turbines are a relatively new source of community noise, and as such their effects on health have yet to be fully described. We report a study exploring the effect of wind turbine noise on health and wellbeing in a sample of New Zealand residents living within two kilometres of a wind turbine installation. Our data provide evidence that wind turbine noise can degrade aspects of health-related quality of life and amenity. On this evidence, wind turbine installations should be sited with care and consideration with respect to the communities hosting them.

Swinbanks, M.A.,
Numerical simulation of infrasound perception, with reference to prior reported laboratory effects.
Presented at Inter-noise 2012, New York City, NY

Abstract
In earlier presentations, the author has argued that conventional assessments of the perception of infrasound based on mean (rms derived) sound energy levels underestimate the importance of the associated crest factor of very low frequency sound pressure variations. By simulating the dynamic response of the ear at levels close to the hearing threshold, it is apparent that infrasound may be perceptible at lower levels than those based on long time constant rms assessment. In particular, it will be shown that the existence of a finite threshold of audibility, together with the added presence of low level higher frequency noise in the first critical band (i.e. below 100Hz), can imply the perception of infrasound at significantly lower levels than has hitherto been acknowledged. The results of simulations will be compared to independently reported effects which have been observed in laboratory testing by other researchers.

Conclusion (excerpt)
The dBG levels for the wind-turbine infrasound inside the house are 10-15dB lower than the Chen test signal which gave rise to adverse effects after only 1 hour. But since there is an 8dB increase in sensitivity for 10% of young adults, it is clear that these infrasonic wind turbine levels could be expected to become a problem after several hours of exposure.