

# **Industrial Wind Turbines and Health: Wind Turbines Can Harm Humans if too close to Residents <sup>1</sup>**

**A summary of some peer reviewed and conference articles, their abstracts  
and citations, regarding adverse health effects and wind turbines <sup>2</sup>**

**Compiled November 1, 2012**

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**Wind Turbine Acoustic Investigation: Infrasound and Low-Frequency Noise--A Case  
Study**

**Stephen E. Ambrose, Robert W. Rand and Carmen M. E. Krogh  
DOI: 10.1177/0270467612455734**

**Bulletin of Science Technology & Society published online 17 August 2012  
<http://bst.sagepub.com/content/early/2012/07/30/0270467612455734>**



**Bio:** Stephen E. Ambrose has more than 35 years of experience in industrial noise control. Board Certified and Member INCE since 1978, he runs a small business providing cost-effective environmental noise consulting services for industrial and commercial businesses, municipal and state governments, and private citizens.

**Bio:** Robert W. Rand has more than 30 years of experience in industrial noise control, environmental sound and general acoustics. A Member INCE since 1993, he runs a small business providing consulting, investigator, and design services in acoustics.

**Bio:** Carmen M. E. Krogh, BScPharm, provided research and reference support. She is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was former Director of Publications and Editor-in-Chief of the Compendium of Pharmaceutical and Specialties (CPS), the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

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<sup>1</sup> 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.”

<sup>2</sup> This summary focuses on published literature 2010 to March 2012 associated with risks to health. References are not intended to be exhaustive.

## **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.

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### **Falmouth, Massachusetts wind turbine infrasound and low frequency noise measurements**

**Stephen E. Ambrose, Robert W. Rand and Carmen M. E. Krogh**  
**Invited paper presented at Inter-noise 2012m New York City, NY**



**Bio:** Stephen E. Ambrose has more than 35 years of experience in industrial noise control. Board Certified and Member INCE since 1978, he runs a small business providing cost-effective environmental noise consulting services for industrial and commercial businesses, municipal and state governments, and private citizens.

**Bio:** Robert W. Rand has more than 30 years of experience in industrial noise control, environmental sound and general acoustics. A Member INCE since 1993, he runs a small business providing consulting, investigator, and design services in acoustics.

**Bio:** Carmen M. E. Krogh, BScPharm, provided research and reference support. She is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was former Director of Publications and Editor-in-Chief of the Compendium of Pharmaceutical and Specialties (CPS), the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

## **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.

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**Relevance and applicability of the Soundscape concept to physiological or behavioural effects caused by noise at very low frequencies which may not be audible**

**Bray, Wade,**

**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.

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**The Noise from Wind Turbines: Potential Adverse Impacts on Children's Well-Being**

**Arline L. Bronzaft**

**Bulletin of Science Technology & Society 2011 31: 256, DOI:**

**10.1177/0270467611412548.**

<http://bst.sagepub.com/content/31/4/291>



**Bio:** Dr. Arline L. Bronzaft is a Professor Emerita of Lehman College, City University of New York. She serves on the Mayor’s GrowNYC, having been named to this organization by three previous Mayors as well. Dr. Bronzaft is the author of landmark research on the effects of elevated train noise on children’s classroom learning; has examined the impacts of airport-related noise on quality of life; and has published articles on noise in environmental books, academic journals and the more popular press. In 2007, she assisted in the updating of the New York City Noise Code.

## **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.

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### **Wind Turbine Noise**

**John P. Harrison**

**Bulletin of Science Technology & Society 2011 31: 256, DOI:**

**10.1177/0270467611412549**

<http://bst.sagepub.com/content/31/4/256>



**Bio:** Dr. John P. Harrison has expertise in the properties of matter at low temperatures with emphasis on high frequency sound waves (phonons). For the past 5 years he has studied wind turbine noise and its regulation. He has presented invited talks on the subject at 3 conferences, including the 2008 World Wind Energy Conference.

## **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.

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**Editorial: Wind turbine noise**

**Christopher D Hanning and Alun Evans**

**British Medical Journal, BM J2 012;344 doi: 10.1136/ bmj.e1527 (8 March 2012)**

[www.bmj.com](http://www.bmj.com)

**BMJ**

**Bio:** Christopher Hanning, BSc, MB, BS, MRCS, LRCP, FRCA, MD is an honorary consultant in sleep medicine Sleep Disorders Service, University Hospitals of Leicester, Leicester General Hospital, Leicester, UK

Dr Chris Hanning is Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, UK. He retired in September 2007 as Consultant in Sleep Disorders Medicine.

After initial training in anaesthesia, he developed an interest in Sleep Medicine. He founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the UK. He was a founder member and President of the British Sleep Society

His expertise in this field has been accepted by the civil, criminal and family courts. He chairs the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sits on Advisory panels for several companies with interests in sleep medicine.

**Bio:** Alun Evans, is an epidemiologist, Centre for Public Health, Queen's University of Belfast, Institute of Clinical Science B, Belfast, UK

**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 ...

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**Literature Reviews on Wind Turbines and Health : Are They Enough?**

**Brett Horner, Roy D. Jeffery and Carmen M. E. Krogh**

**Bulletin of Science Technology & Society 2011 31: 399.**

**DOI: 10.1177/0270467611421849**

<http://bst.sagepub.com/content/31/5/399>



**Bio:** Brett Horner, BA, is a certified management accountant and has held senior manager positions in international business consulting groups. He has provided information technology consulting and accounting/auditing services to a wide variety of clientele. He has dedicated over 2 years reviewing and analyzing references on the subject of industrial wind turbines and reported health effects.

**Bio:** Roy D. Jeffery, MD, is a rural family physician and a clinical preceptor for the University of Ottawa and the Northern Ontario Medical Schools. He practices rural medicine with special interests regarding geriatric home care and rural health. He has the distinction of being awarded the Ontario Family Physician of the Year–Northern Division in 2008.

**Bio:** Carmen M. E. Krogh, BSc Pharm, is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was a former director of Publications and editor-in-chief of the Compendium of Pharmaceutical and Specialties, the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

**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.

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**Wind Turbine Infra and Low-Frequency Sound: Warnings Signs That Were Not Heard**

**Richard R James**

**DOI: 10.1177/0270467611421845**

**Bulletin of Science Technology & Society published online 15 December 2011**

<http://bst.sagepub.com/content/early/2011/11/07/0270467611421845>



**Bio:** Richard R. James, Institute of Noise Control Engineering, has been actively involved in the field of noise control since 1969, participating in and supervising research and engineering projects related to control of occupational and community noise. He has performed extensive acoustical testing and development work for a variety of complex environmental noise problems using both classical and computer simulation techniques. Since 2006, he has been involved with noise and health issues related to industrial wind turbines.

**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.

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**Wind Turbines Make Waves:**

**Why Some Residents Near Wind Turbines Become Ill**

**Magda Havas and David Colling**

**Bulletin of Science Technology & Society 2011 31: 414. DOI: 0.1177/0270467611417852**

<http://bst.sagepub.com/content/31/5/369>



**Bio:** Magda Havas, PhD, is an associate professor at Trent University where she teaches and conducts research on the biological and health effects of electromagnetic and chemical

pollutants. She received her BSc and PhD at the University of Toronto and did postdoctoral research at Cornell University on acid rain and aluminum toxicity.

**Bio:** David Colling has applied his electrical engineering studies at Ryerson Polytechnical Institute and his specialized training in electrical pollution to conduct electrical pollution testing for Bio-Ag on farms, homes, and office buildings. Some of the homes tested are located in the environs of industrial wind turbines.

### **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.

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### **Industrial Wind Turbine Development and Loss of Social Justice?**

**Carmen M.E. Krogh**

**Bulletin of Science Technology & Society 2011 31: 321, DOI:  
10.1177/0270467611412550,**

<http://bst.sagepub.com/content/31/4/321>



**Bio:** Carmen M. E. Krogh, BScPharm is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association and Health Canada. She was a former Director of Publications and Editor-in-chief of *the Compendium of Pharmaceutical and Specialties (CPS)*, the book used in Canada by physicians, nurses and other health professions for prescribing information on medication.

### **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.

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**WindVOiCe, a Self-Reporting Survey: Adverse Health Effects, Industrial Wind Turbines, and the Need for Vigilance Monitoring**

**Carmen M.E. Krogh, Lorrie Gillis, Nicholas Kouwen, and Jeffery Aramini**

**Bulletin of Science Technology & Society 2011 31: 334,**

**DOI: 10.1177/0270467611412551,**

<http://bst.sagepub.com/content/31/4/334>



**Bio:** Carmen M. E. Krogh, BScPharm is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association and Health Canada. She was a former Director of Publications and Editor-in-chief of the *Compendium of Pharmaceutical and Specialties (CPS)*, the book used in Canada by physicians, nurses and other health professions for prescribing information on medication.

**Bio:** Ms Lorrie Gillis is the process administrator for the WindVOiCe health survey. Ms Gillis volunteers her time and ensures the processes for administering the protocols are maintained.

**Bio:** Dr. Nicholas Kouwen is a Distinguished Professor Emeritus in the Department of Civil and Environmental Engineering of the University of Waterloo, Waterloo, Ontario, Canada. He is a registered Professional Engineer (Ontario) and a Fellow of the American Society of Civil Engineers. His field of expertise is in hydraulic and hydrological modelling and is currently involved in studies dealing with the impact of climate change on water availability.

**Bio:** Dr. Jeff Aramini is a public health epidemiologist with expertise in the investigation of health concerns using epidemiological principles. DVM and M.Sc. from the University of Saskatchewan; Ph.D. from the University of Guelph. Former senior epidemiologist with Health Canada/Public Health Agency of Canada. Currently, President and CEO of an organization that addresses public health, patient care, public safety and information management for clients in government, industry and academia.

## **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.

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



**Bio:** Carmen M. E. Krogh, BSc Pharm, is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was a former director of Publications and editor-in-chief of the Compendium of Pharmaceutical and Specialties, the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

**Bio:** Roy D. Jeffery, MD, is a rural family physician and a clinical preceptor for the University of Ottawa and the Northern Ontario Medical Schools. He practices rural medicine with special interests regarding geriatric home care and rural health. He has the distinction of being awarded the Ontario Family Physician of the Year–Northern Division in 2008.

**Bio:** Dr. Jeff Aramini is a public health epidemiologist with expertise in the investigation of health concerns using epidemiological principles. DVM and M.Sc. from the University of Saskatchewan; Ph.D. from the University of Guelph. Former senior epidemiologist with Health Canada/Public Health Agency of Canada. Currently, President and CEO of an organization that addresses public health, patient care, public safety and information management for clients in government, industry and academia.

**Bio:** Brett Horner, BA, is a certified management accountant and has held senior manager positions in international business consulting groups. He has provided information technology consulting and accounting/auditing services to a wide variety of clientele. He has dedicated over 2 years reviewing and analyzing references on the subject of industrial wind turbines and reported health effects.

## **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.

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



**Bio:** Carmen M. E. Krogh, BSc Pharm, is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was a former director of Publications and editor-in-chief of the Compendium of Pharmaceutical and Specialties, the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

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**Bio:** Brett Horner, BA, is a certified management accountant and has held senior manager positions in international business consulting groups. He has provided information technology consulting and accounting/auditing services to a wide variety of clientele. He has dedicated over 2 years reviewing and analyzing references on the subject of industrial wind turbines and reported health effects.

## **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.

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



**Bio:** Carmen M. E. Krogh, BSc Pharm, is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was a former director of Publications and editor-in-chief of the Compendium of Pharmaceutical and Specialties, the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

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**Bio:** Brett Horner, BA, is a certified management accountant and has held senior manager positions in international business consulting groups. He has provided information technology consulting and accounting/auditing services to a wide variety of clientele. He has dedicated over 2 years reviewing and analyzing references on the subject of industrial wind turbines and reported health effects.

### **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.

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### **Low-frequency noise from large wind turbines**

**Henrik Møller and Christian Sejer Pedersen**

**Section of Acoustics, Aalborg University,**

**Fredrik Bajers Vej 7-B5, DK-9220 Aalborg Ø, 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 (<math>2</math> 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.

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**Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis**

**Robert Y. McMurtry**

**Bulletin of Science Technology & Society 2011 31: 316, DOI:**

**10.1177/0270467611415075,**

<http://bst.sagepub.com/content/31/4/316>



**Bio:** Dr. Robert Y. McMurtry is the former Dean of Medicine for the University of Western Ontario. He was a member of the Health Council of Canada for 3½ years and a member and special advisor to the Royal Commission under Roy Romanow on the future of health care in Canada. Dr. McMurtry was a visiting Cameron Chair to Health Canada for providing policy advice to the Minister and Deputy Minister of Health. He was the Founding and Associate Deputy Minister of Population & Public Health, Canada. Dr. McMurtry also sat on the National Steering Committee on Climate Change and Health Assessment. Presently Dr. McMurtry is Professor (Emeritus) of Surgery, University of Western Ontario.

**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.

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**Effects of industrial wind turbine noise on sleep and health**  
**Nissenbaum, Michael A., Aramini, Jeffery J., Hanning, Christopher D.**  
**Noise & Health, September-October 2012, Volume 14, p243**  
[www.noiseandhealth.org](http://www.noiseandhealth.org)



**Bio:** Dr. Michael A. Nissenbaum received his undergraduate education at McGill University in Montreal and completed medical school at the University of Toronto. He specialized in diagnostic imaging and completed his residency at McGill University. He received a Fellowship from the University of California. Currently, Dr. Nissenbaum is certified by the Royal College of Physicians of Canada, and American Board of Radiology. He is a radiologist at the Northern Maine Medical Center, Fort Kent, Maine. Previous positions include Junior Faculty at Harvard University and Associate Director of MRI at a major Harvard teaching hospital.

**Bio:** Dr. Jeff Aramini is a public health epidemiologist with expertise in the investigation of health concerns using epidemiological principles. DVM and M.Sc. from the University of Saskatchewan; Ph.D. from the University of Guelph. Former senior epidemiologist with Health Canada/Public Health Agency of Canada. Currently, President and CEO of an organization that addresses public health, patient care, public safety and information management for clients in government, industry and academia.

**Bio:** Dr Chris Hanning is Honorary Consultant in Sleep Disorders Medicine to the University Hospitals of Leicester NHS Trust, UK. He retired in September 2007 as Consultant in Sleep Disorders Medicine. After initial training in anaesthesia, he developed an interest in Sleep Medicine. He founded and ran the Leicester Sleep Disorders Service, one of the longest standing and largest services in the UK. He was a founder member and President of the British Sleep Society. His expertise in this field has been accepted by the civil, criminal and family courts. He chairs the Advisory panel of the SOMNIA study, a major project investigating sleep quality in the elderly, and sits on Advisory panels for several companies with interests in sleep medicine.

**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.

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**Properly Interpreting the Epidemiologic Evidence About the Health Effects of Industrial Wind Turbines on Nearby Residents**

**Carl V. Phillips**

Bulletin of Science Technology & Society 2011 31: 303, DOI: 10.1177/0270467611412554,  
<http://bst.sagepub.com/content/31/4/303>



**Bio:** Dr. Carl V. Phillips is a consultant and author specializing in epidemiology, science-based policy making, and communicating scientific concepts to the public. He spent most of his career as a professor of public health and now works in litigation support, scientific advising, and grant-supported research. He blogs at [ep-ology.blogspot.com](http://ep-ology.blogspot.com), which provides links to his other writings.

**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.



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## Occupational Health and Industrial Wind Turbines: A Case Study

Robert W. Rand, Stephen E. Ambrose, and Carmen M. E. Krogh

Bulletin of Science Technology & Society 2011 31: 359DOI: 10.1177/0270467611417849

<http://bst.sagepub.com/content/31/5/359>



**Bio:** Robert W. Rand is a principal author with over 30 years of experience in industrial noise control, environmental sound, and general acoustics. A member of the Institute of Noise Control Engineering since 1993, he runs a small business providing consulting, investigator, and design services in acoustics.

**Bio:** Stephen E. Ambrose is a principal author with over 35 years of experience in industrial noise control. A member of the Institute of Noise Control Engineering since 1978, he runs a small business providing cost-effective environmental noise consulting services for industrial and commercial businesses, municipal and state governments, and private citizens.

**Bio:** Carmen M. E. Krogh, BScPharm, who provided health-related research and reference support, is a retired pharmacist with more than 40 years of experience in health. She has held senior executive positions at a major teaching hospital, a professional association, and Health Canada. She was a former Director of Publications and Editor in Chief of the *Compendium of Pharmaceutical and Specialties (CPS)*, the book used in Canada by physicians, nurses, and other health professions for prescribing information on medication.

### 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.

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**Responses of the ear to low frequency sounds, infrasound and  
wind turbines.**

**Alec N. Salt and T.E. Hullar.**

**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.

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

**Bio:** Alec N. Salt received his PhD from the University of Birmingham, UK, in 1977 and has been actively involved in research into the physiology of the ear for over 35 years.

**Bio:** Dr. Lichtenhan is from the Eaton-Peabody Laboratory, Massachusetts Eye & Ear Infirmary, Boston Massachusetts and the Department of Otology & Laryngology, Harvard Medical School, Boston, Massachusetts.

**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 enhanced 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.

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



**Bio:** Alec N. Salt received his PhD from the University of Birmingham, UK, in 1977 and has been actively involved in research into the physiology of the ear for over 35 years.

**Bio:** James A. Kaltenbach received his PhD from the University of Pennsylvania in 1984. He specializes in the neurobiology of hearing disorders and is currently the Director of Otology Research at the Cleveland Clinic.

## **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.

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### **Perception-based protection from low-frequency sounds may not be enough**

**Alec N. Salt and Jeffery T. Lichtenhan**

**Invited paper presented at Inter-noise 2012, New York City, NY**



**Bio:** Alec N. Salt, Department of Otolaryngology, Washington University School of Medicine, St. Louis, MO, received his PhD from the University of Birmingham, UK, in 1977 and has been actively involved in research into the physiology of the ear for over 35 years.

## **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.

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**Public Health Ethics, Legitimacy, and the Challenges of Industrial Wind Turbines: The Case of Ontario, Canada**

**Martin Shain**

**Bulletin of Science Technology & Society, 2011 31: 256**

**DOI: 10.1177/0270467611412552,**

<http://bst.sagepub.com/content/31/4/346>



**Bio:** Martin Shain S.J.D. is trained in law and social sciences. He is principal and founder of the Neighbour at Work Centre® and assistant professor at the Dalla Lana School of Public Health, Occupational and Environmental Health Division, University of Toronto.

**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.

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**Mitigating the Acoustic Impacts of Modern Technologies: Acoustic, Health, and Psychosocial Factors Informing Wind Farm Placement**

**Daniel Shepherd and Rex Billington**

**Bulletin of Science Technology & Society 2011 31: 389**

**DOI: 10.1177/0270467611417841**

<http://bst.sagepub.com/content/31/5/389>



**Bio:** Daniel Shepherd has a PhD in psychoacoustics and holds a lectureship at the Faculty of Health, AUT University. As an environmental psychologist, he researches the psychological response to noise from both individual and social perspectives.

**Bio:** Dr. Rex Billington is a research health psychologist at AUT University after 18 years with the World Health Organization including directorships in Mental Health and the Global Program on AIDS.

### **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.

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**Evaluating the impact of wind turbine noise on health related quality of life  
by Daniel Shepherd, David McBride, David Welch, Kim N. Dirks, Erin M. Hill  
Noise & Health, September-October 2011, 13:54,333-9**

**DOI: 10.4103/1463-1741.85502**

[www.noiseandhealth.org](http://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.

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**The Problems With "Noise Numbers" for Wind Farm Noise Assessment**

**Bob Thorne**

**Bulletin of Science Technology & Society 2011 31: 262**

**DOI: 10.1177/0270467611412557,**

<http://bst.sagepub.com/content/31/4/262>



**Bio:** Bob Thorne, MSc, PhD, is the principal consultant of Noise Measurement Services Pty Ltd, Brisbane, Australia. He holds a PhD from Massey University, New Zealand, in health science and is an environmental health research associate in the Institute of Food, Nutrition and Human Health at Massey University. His research work involves using advanced specialized technology for intrusive noise assessment, and a specific application is personalized sound reinforcement for hearing assistive devices.

**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 a tonal 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.