# Wind Turbine Noise: Effects on Human Health

*Health Impacts of Industrial Wind Projects: A Public Health Presentation*
*Sponsored by Senator Robert Ortt*
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# Topic Outline



- Annoyance from audible noise and infrasound
- Causal links between low-frequency noise and adverse health effects
- Relevant noise guidelines
- Observations from personal interviews

# My First View of Wind Turbines (Huron County, Michigan)



# Huron County, Michigan Family Home



This family was sleeping in a motel during nights when the turbines were fully operational.

# Wind Turbine Noise: Professional Experience



- Visited wind project in Huron County, MI (2009)
- Read book by Paul Gipe, *Wind Energy Comes of Age*
- Searched Internet and reviewed literature about life near wind turbines
- Published literature review article in *Audiology Today* in 2010
- Chaired Wind and Health Technical Work Group, MI Department of Energy
- Presented invited comments in public meetings and hearings of zoning boards and commissions in several states (MI, IL, IN, NY)
- Co-authored three-part, invited article (hearinghealthmatters.org)
- Qualified legally as health expert in Daubert hearing (MI)
- Served or serving as witness, as health expert, in legal cases (OH, WI, MI, IA, IL, OR, IN, NY, SD), before or after turbine construction
- Interviewed individuals and families who had abandoned, or about to abandon, their homes (MI, IA, OR)
- Co-authored 2016 literature review (with R. James): *Wind turbine noise and human health: a four-decade history of evidence that wind turbines pose risks*

# Specific vs. General Causation



- *Specific causation* usually requires that a physician determine what is causing the symptoms of an individual patient (e.g., abdominal pain is caused by a gall bladder attack).
  - Minimum requirements (IWT cases): Medical education, individual contact, knowledge of acoustics and its effects on people
- *General causation* usually requires that a scientist (or other expert) determine what is causing symptoms of people in a particular population (e.g., cigarette smoking causes lung cancer in a significant number of people).
  - Minimum requirements (IWT cases): Education in epidemiology or other health-related field, research background, site visits, resident interviews, knowledge of acoustics and its effects on people

# Abbreviations



AHEs: Adverse health effects

IWTs: Industrial wind turbines

WHO: World Health Organization

# Nuisance, Annoyance, and Health



- Nuisance is a term used mainly in state and local noise-control regulations to protect the use and enjoyment of personal property.
- The WHO treats nuisance and annoyance as essentially the same thing, defining *annoyance* as "any sound that is perceived as irritating or a nuisance." (p. 142)
- The WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."
- Scientific studies show wind turbine noise to be annoying to a substantial percentage of the population; the WHO considers noise-induced annoyance as a potential factor leading to a deterioration of health.

# Numerous research studies link annoyance and low-frequency noise



- Kelley et al (1982)*
- Kelley et al (1985)*
- Kelley (1987)*
- Bradley (1994); HVAC systems
- Leventhall (2004); occupational settings
- Pedersen & Waye (2004)*
- van den Berg (2004)*
- Pedersen & Waye (2007)*
- Pedersen et al (2009)*
- Janssen et al (2010)*
- Harrison (2011)*
- Shepherd et al (2011)*
- Palmer (2013)*

*Study dealt specifically with low-frequency noise from wind turbines. See Punch & James, 2016, for full references.

# IWTs have many annoying characteristics



- ***Industrial wind turbines produce pulsed, amplitude-modulated, tonal sounds that are unpredictable, uncontrollable (by receptors), and sleep-disturbing.***
- *Amplitude-modulated* and *impulsive* noises are more easily perceived and more annoying than constant-level noise (Sutherland & Burke, 1979; Bradley, 1994).
- *Tonal sounds* are more annoying than sounds containing energy across a broad range of frequencies (Moorhouse et al, 2005; Bray, 2007; Swinbanks, 2012).
- Sounds that are *unpredictable* and *uncontrollable* increase noise annoyance (Geen & McCown, 1984; Hatfield et al, 2002).
- *Nighttime noise* is more annoying than daytime noise (Berger et al, 2015; Berglund et al, 1999; WHO, 2009).
- *Rural noise* is more annoying than urban noise (Pedersen & Waye, 2007).

# IWT noise is much more annoying than aircraft, traffic, or rail noise



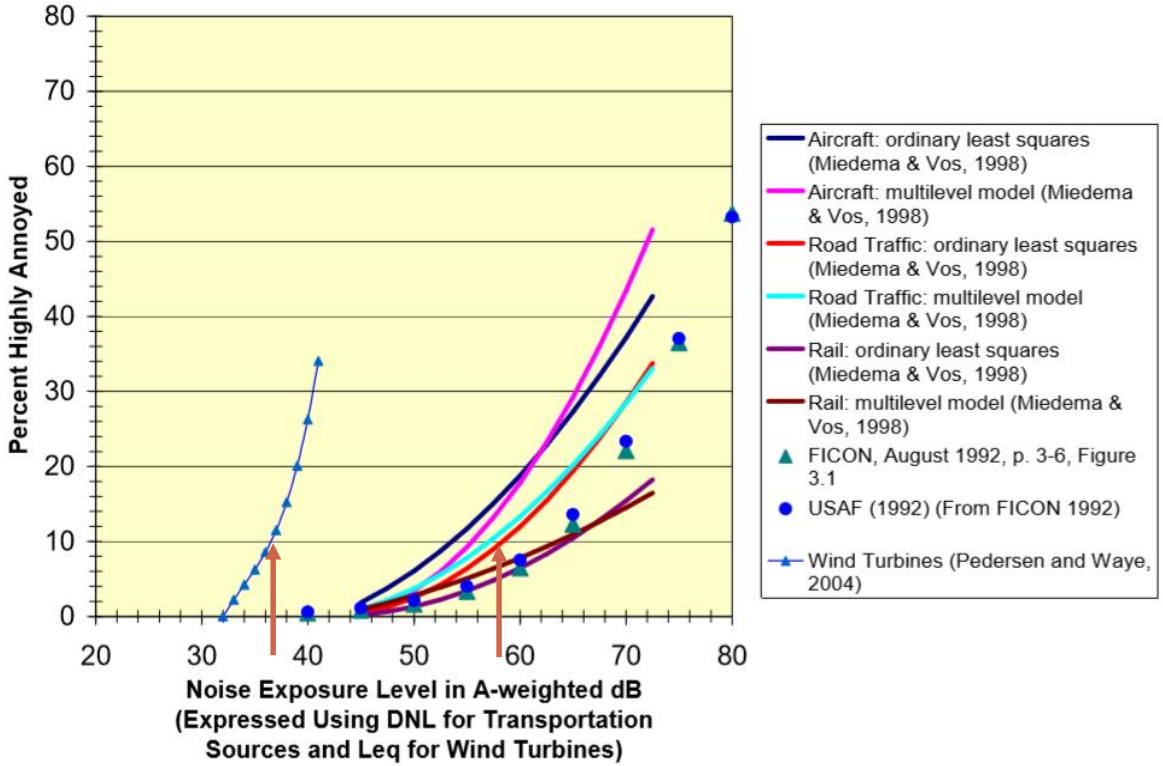
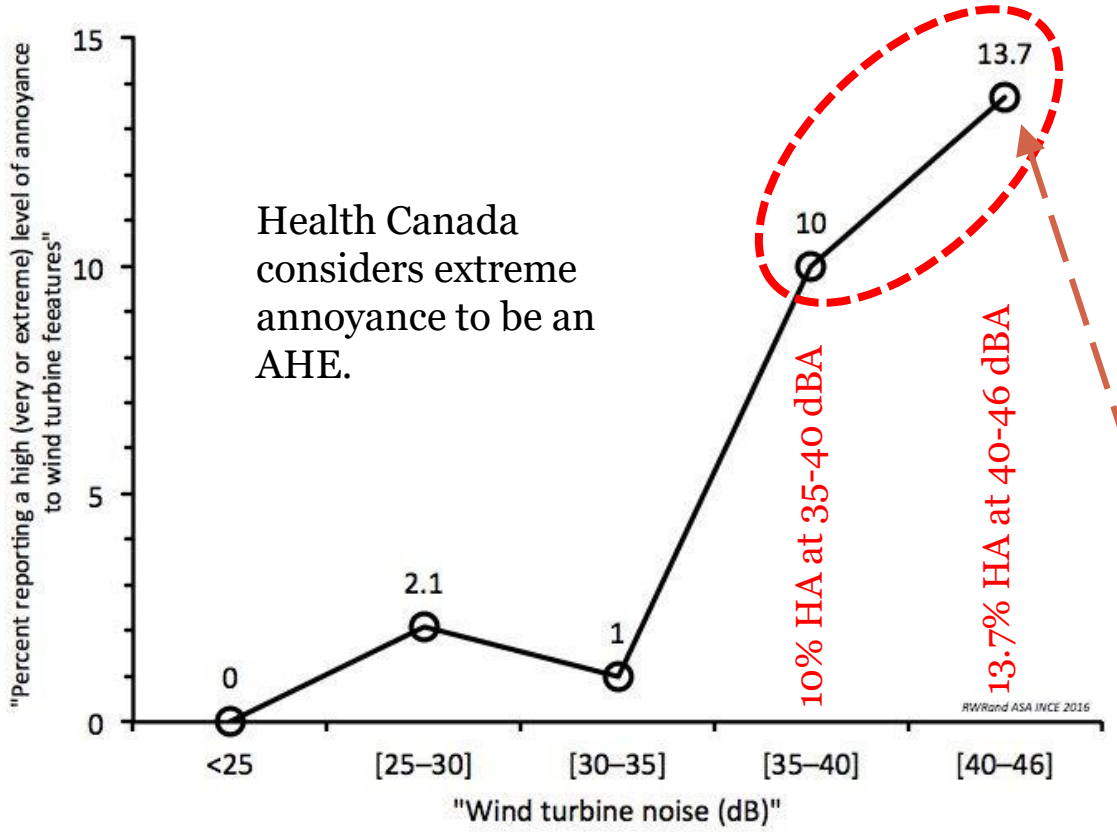



**Figure 1:** Dose-response relationships for transportation sources and wind turbines

Source: Graph replotted from Pedersen, E., & Persson Waye, K. P. (2004). Perception and annoyance due to wind turbine noise—a dose-response relationship. Journal of the Acoustical Society of America, 116, 3460-3470.

# The Health Canada study found IWT noise highly annoying in a substantial number of people






Health Canada considers extreme annoyance to be an AHE.

*Data source: "Exposure to wind turbine noise: Perceptual responses and reported health effects", TABLE IV. Perception of community noise and related variables, Variable "Reporting a high (very or extreme) level of annoyance to wind turbine features: Noise", D.S. Michaud et al, Health Canada, J. Acoust. Soc. Am. 139 (3), March 2016.*

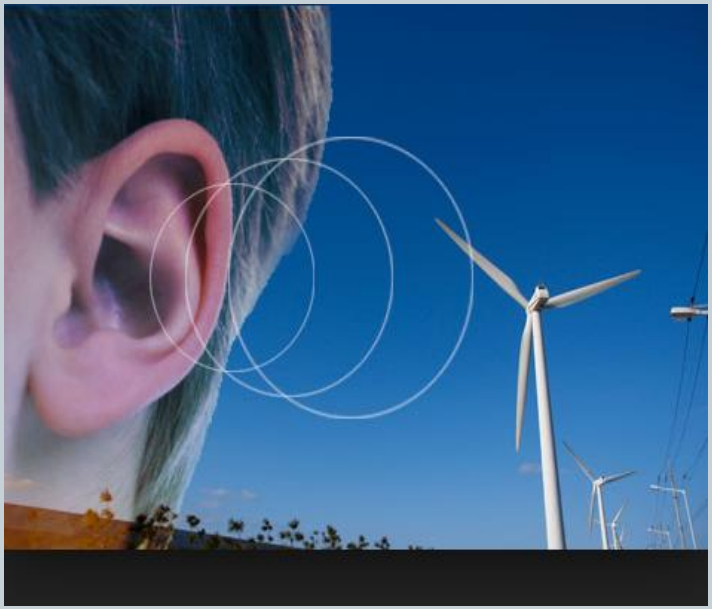
At least 1 out of 10 people in project area who were exposed to levels >35 dBA were highly annoyed.

Receptors who are exposed to levels above 40 dBA will experience higher annoyance levels.

# Is infrasound an exception?



- Leventhall (2006): “Infrasound .. is below the audible threshold and of no consequence….What we can’t hear can’t hurt us.”
- Alec Salt, Ph.D.: This logic seems to apply ONLY to hearing, and he asks us to consider the other senses.
- Can things we can’t taste, smell, see, or touch not hurt us?
- Why should hearing be any different?



# IWT exposure leads to a common set of symptoms



Nina Pierpont, M.D., Ph.D., and a pediatric neurologist, described 10 symptoms, labeled *Wind Turbine Syndrome*, in a 2009 book by the same name; many other researchers have since observed similar symptoms.

- Sleep disturbance
- Headache
- Visceral Vibratory Vestibular Disturbance (VVVD)
- Dizziness, vertigo, unsteadiness
- Tinnitus
- Ear pressure or pain
- External auditory canal sensation
- Memory and concentration deficits
- Irritability and anger
- Fatigue and loss of motivation

# Wind turbine infrasound causes adverse sensations



- In a controlled, visually blinded field study and a separate laboratory study, Australians Steven Cooper and Chris Chan showed that inaudible sound pulsations of wind turbines, occurring at infrasonic rates, caused unpleasant perceptible “sensations” that were synchronized with wind turbine operation.
- Sensations included headache; pressure in the head, ears, or chest; ringing in the ears; heart racing; or a sensation of heaviness.
- Alternative explanations, such as the so-called *nocebo effect*, have been refuted by finding a direct cause-effect relationship between infrasound and AHEs.

# IWT noise has been linked to a large number of AHEs*

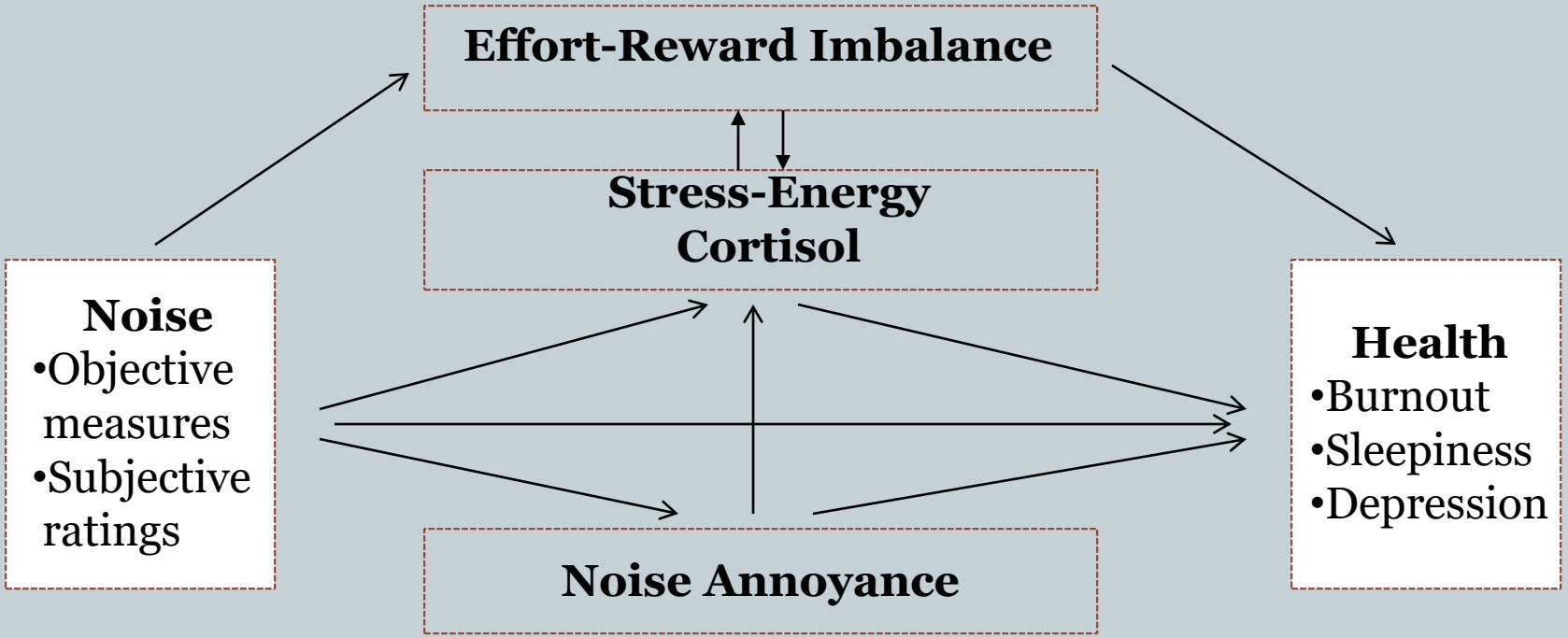


- Wind Turbine Syndrome (some symptoms)
- Sensations reported by Cooper's research
- Additional reported symptoms
  - Vomiting
  - Migraine headaches
  - Changes in heart rate
  - Visual blurring
  - Anxiety
  - Reduced quality of life

*Alves-Pereira et al. (2018) explain some of the biological effects of infrasound, especially for high-level, sustained exposures: file:///C:/Users/jpunch/Documents/Adobe/Work%20PDFs/Wind%20Turbine%20Noise%20Literature/Alves-Pereira%20et%20al%20(2018).pdf.

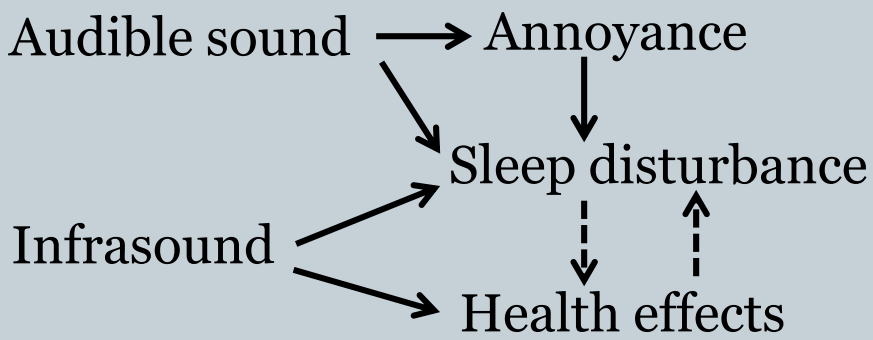
# Noise and health are linked directly and indirectly





# Schomer classifies the effects of audible noise and infrasound on health (modified)






Example: Wind turbine noise can cause awakenings, and chronic awakenings can lead to AHEs.

→ Direct pathway

⇢ Indirect pathway

# Sleep disturbance is the most well-documented symptom*



- Leventhall (2003)
- Minnesota Department of Health (2009)
- Pedersen (2009, 2011)
- Masotti & Hodgetts (2011)
- Shepherd & Billington (2011)
- Shepherd et al. (2011)
- Thorne (2011, 2013)
- Krogh et al. (2012)
- Nissenbaum et al. (2012)
- Jeffery et al. (2013)
- Nissenbaum (2013)
- Paller et al. (2013)
- Palmer (2013)
- Taylor (2013)
- Kasprzak (2014)

*See Punch & James, 2016, for full references.

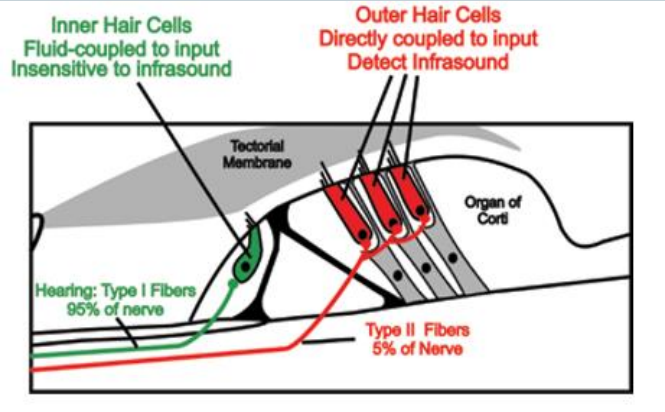
# Sleep disturbance adversely affects health: National Institutes of Health



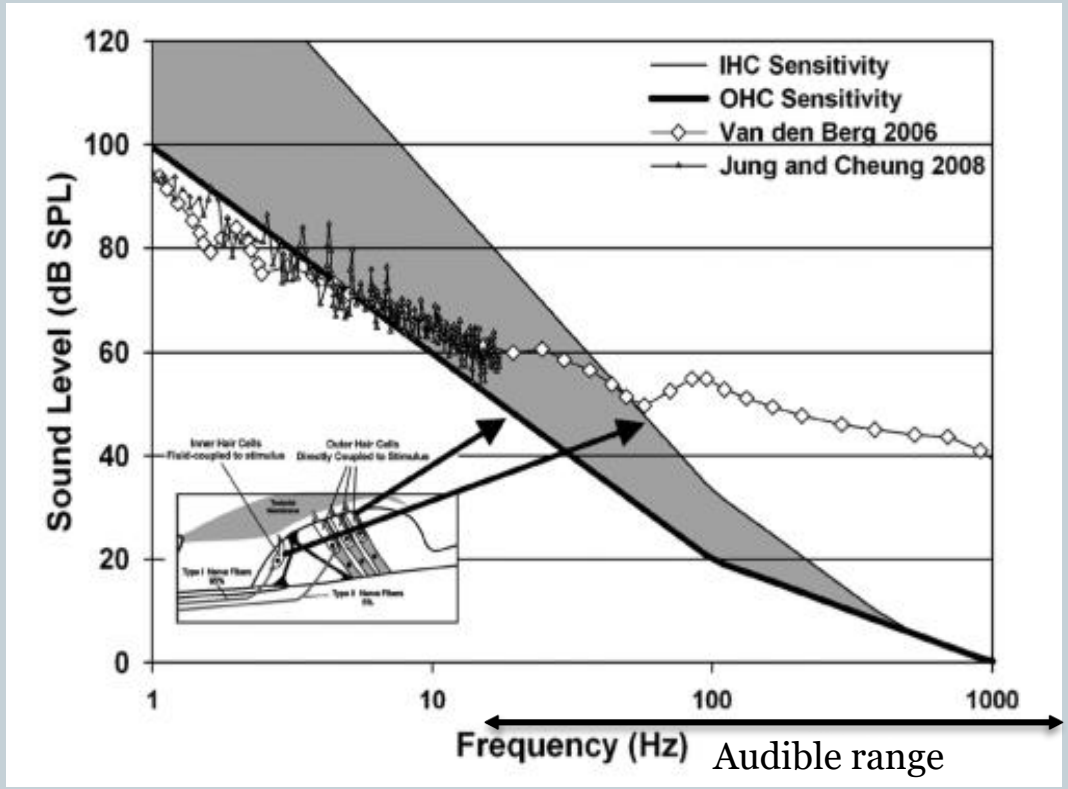
- Hypertension
- Negative effects on memory, temperament, heart rate, heart health, and hormones
- Reduced capacity to learn new information, concentrate, and recall information
- Lowered immunity to disease, weight gain; negative effects on childhood growth and development, muscle growth and tissue repair in children and adults
- Negative effects on puberty and fertility

# There is a physiologic basis for the negative effects of infrasound






OHCs of inner ear are sensitive to infrasound (< 10 Hz) at levels too low to be heard as sound, but infrasound can reach non-auditory centers of the brain, resulting in negative sensations such as dizziness and nausea, seasickness, fear and alerting responses such as startle and wakefulness, and difficulties with visually based problem-solving. The concept that "What you can't hear can't affect you" is invalid.

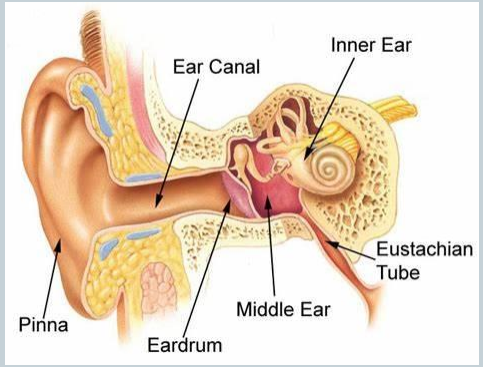


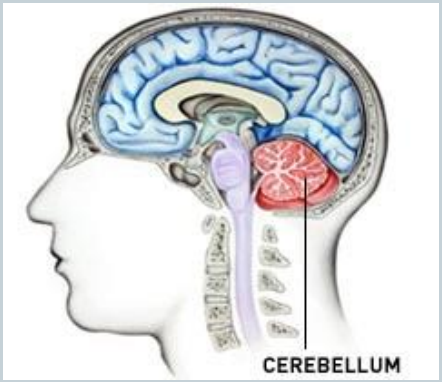

Sources: Salt, 2011; Salt & Kaltenbach, 2011

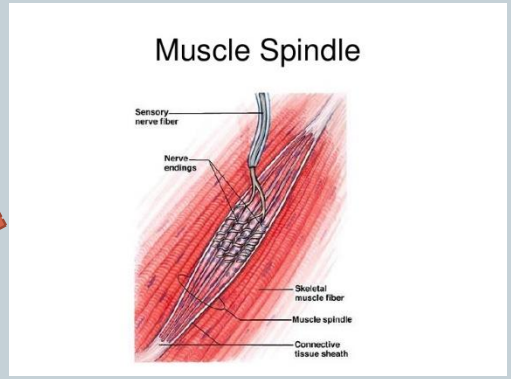
# Exposure to IWT infrasound can lead to motion sickness

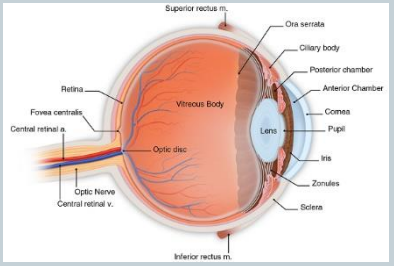


Motion sickness occurs when the senses of balance (inner ear), vision, and muscle receptors receive *conflicting information*. (These sensory inputs converge in the cerebellum.)




The cerebellum receives input from sensory systems of the spinal cord and from other parts of the brain, and integrates these inputs to coordinate movement, balance, and posture.

# Setbacks that protect physical safety are insufficient to protect health



- Most of the reported health symptoms have been observed at distances much greater than commonly used setback distances.
- Setbacks intended to protect physical safety from mechanical or other traumatic failure of a wind turbine component are not adequate to protect general health and well-being.

# Some major U.S. and international guidelines are used to limit noise exposure



- **U. S. Environmental Protection Agency (EPA)**

Noise Control Act (1972) and Quiet Communities Act (1978)
Not updated, but link noise to stress-related illnesses and other AHEs

- **ISO 1996-1 and ANSI S12.9 Part 4 Standards**

Recommend 15-dB penalty for new noise sources in quiet, rural communities

- **National Association of Regulatory Utility Commissioners (NARUC, 2011) and NY Department of Environmental Conservation (DEC, 2001)**

Recommend limiting noise levels to 5 or 6 dB above background levels; given rural background levels of $\leq$30 dBA (1-hr. Leq) at night, nighttime IWT noise often exceeds guidelines

- **WHO (1999, 2009, 2018)**

Developed in Europe and used worldwide to limit noise levels for the purpose of limiting annoyance and AHEs

- **Schomer and Pamidighantam (2017)**

Recommend maximum permissible levels averaging 36-38 dBA, measured over a 24-hour period, to protect against substantial annoyance and AHEs from wind turbine noise (based on four independent studies)

# The WHO noise guidelines limit community, transportation, and industrial noise levels



- WHO (Berglund et al., 1999; community noise)
  - For continuous nighttime noise, indoor levels should not exceed 30 dB LAeq, and outdoor levels should not exceed 45 dB LAeq. Single noise events should not exceed 45 dB LAmax.
  - Special attention should be given to noise when background noise is low, when noise is combined with vibrations, and when noise consists of low-frequency components.
- WHO (2009; nighttime transportation noise)
  - Outside night noise levels should be limited to 40 dB LAeq, and night, inside noise should be limited to 35-42 dB LAmax (based on transportation noises).
- WHO (2018; environmental noise, including IWT noise)
  - Wind turbine noise level should be limited to 45 dB Lden, which equates to ~38 dB LAeq.
  - This guideline does not provide a specific LAmax recommendation.

# The 2009 WHO noise guidelines were intended to minimize sleep disturbance and AHEs



| Leq(night,outside) | Health Effects |
|---|---|
| <30 dBA | No substantial biological effects |
| 30-40 dBA | Affects sleep: body movements, awakening, self-reported sleep disturbance, arousals; vulnerable groups (young children, elderly adults, persons with chronic health conditions) more susceptible |
| 40-55 dBA | AHEs observed (with vulnerable groups more severely affected) |

World Health Organization

*The above levels are long-term averages and are not based specifically on wind turbine noise, which contains more low-frequency noise than most other industrial and transportation sources, on which these levels are based.*

# Observations from Personal Interviews: Family, State A



## Comparison with Pierpont's Wind Turbine Syndrome Criteria

| *Symptom* | *Mother* | *Father* | *Son* |
|---|---|---|---|
| **Sleep disturbance** | ✓ | ✓ | ✓ |
| **Headache** | | | ✓ |
| **Visceral Vibratory Vestibular Disturbance (VVVD)** | ✓ | | ✓ |
| **Dizziness, vertigo, unsteadiness** | ✓ | | |
| **Tinnitus** | | ✓ | |
| **Ear pressure or pain** | ✓ | ✓ | ✓ |
| **External auditory canal sensation** | ✓ | ✓ | |
| **Memory and concentration deficits** | ✓ | | ✓ |
| **Irritability, anger** | ✓ | ✓ | |
| **Fatigue, loss of motivation** | ✓ | ✓ | ✓ |

# Observations from Personal Interviews: Individual Resident, State B



## Comparison with Pierpont's Wind Turbine Syndrome Criteria

| *Symptom* | *Adult Male* |
|---|---|
| **Sleep disturbance** | ✓ |
| **Headache** | ✓ |
| **Visceral Vibratory Vestibular Disturbance (VVVD)** | ✓ |
| **Dizziness, vertigo, unsteadiness** | ✓ |
| **Tinnitus** | |
| **Ear pressure or pain** | |
| **External auditory canal sensation** | |
| **Memory and concentration deficits** | ✓ |
| **Irritability, anger** | ✓ |
| **Fatigue, loss of motivation** | ✓ |

# Observations from Personal Interviews: Farm Couple, State C



- From a wife who was having to give up the family farm: "*I didn't know the negative impact windmills can have and the problems they can cause. The relationships in our family, having to move, and the change in our quality of life have not been easy to deal with.*"
- From her husband: "*My wife told me she would rather have a hog building hooked to the house than have a wind turbine close to it…. I also put my bed in a different room away from windows to see if it helped; it didn't help….Everybody told me (including doctor) that I should move because I looked so bad; my body was shutting down….It was my lifelong dream to raise my kids and family on the farm. The wind turbines took this away from me. My doctor told me I needed to do something to regain my health, even if I had to move he said money can't buy your health…. Physical stress and emotional stress would be a good way to sum up the turbines' effects, not to mention sleep deprivation.*"

# Setback distance is the most effective means of controlling IWT noise levels



- IWT noise levels are affected by distance, terrain, weather patterns, number of turbines, turbine height, and the turbine array itself, but the major factors are turbine height and distance from property lines.
- Infrasound and low-frequency noise levels are typically not masked by wind or other noises, and *cannot* be controlled effectively by erecting barriers, insulating homes, or wearing earplugs, so distance is the only practical means of achieving acceptable sound levels.
- Setback distances should be based on the acceptable noise levels at property lines, not residences (i.e., enjoyment of property; waiver an option).

# Specific restrictions on setbacks and noise levels have been recommended



- Setback Distance: To protect human health, recommendations in the literature include minimum distances ranging from 0.5-2.5 miles. The distance recommended most often by researchers is 1.25 mi (2 km), but some now recommend longer setbacks.
- Noise levels: Recommendations in the literature include maximum noise levels ranging from 30-40 dBA (assuming the use of A-weighting). Some local zoning ordinances require that noise levels be limited to 5-10 dB above prevailing background noise levels.

# An Iowa county is advocating for longer IWT setbacks



Based largely on the recommendation of Dr. Ben Johnson, a cardiologist, the following ruling has been adopted in Madison County, Iowa:

"Resolved that the Madison County Board of Health determines that there is the potential for negative health (e)ffects associated with commercial wind turbines and that current setbacks are inadequate to protect the public health. The Board encourages those entities with jurisdiction within the County to require a one and one-half (1-1/2) mile setback for future wind turbine projects."

Madison County, Iowa
August 8, 2019

A comprehensive list of recommended setbacks in the U.S. and other countries is available at: http://www.wiseenergy.org/Energy/Wind_Ordinance/Setbacks.pdf.

# Conclusions



1. Annoyance can lead to stress, which can impact health.
2. Many AHEs have been associated with audible and inaudible wind turbine noise, sleep disturbance being the most common complaint; infrasound has been linked directly to negative sensations and AHEs.
3. Noise limits and setbacks advocated by the wind industry are harmful to the health of a substantial percentage of people.
4. A 1.25 mile (2 km) setback has most often been recommended to avoid annoyance and AHEs; some scientists and regulatory authorities are now recommending longer setbacks.
5. The 2009 and 2018 WHO guidelines recommend limiting noise levels to 38-40 dB LAeq.
6. To prevent sleep disturbance, the 2009 WHO guidelines recommend limiting nighttime low-frequency noise by using LAmax as the preferred metric; LAmax effectively captures the levels of short-term pulsating noise, as opposed to long-term averaged noise levels.

# Punch & James (2016): Major Conclusions



- "The available literature, which includes research reported by scientists and other reputable professionals in peer-reviewed journals, government documents, print and web-based media, and in scientific and professional papers presented at society meetings, is sufficient to establish a general causal link between a variety of commonly observed AHEs and noise emitted by IWTs." (p. 54)
- "A pro-health view is that there is enough anecdotal and scientific evidence to indicate that ILFN from IWTs causes annoyance, sleep disturbance, stress, and a variety of other AHEs to warrant siting the turbines at distances sufficient to avoid such harmful effects, which, without proper siting, occur in a substantial percentage of the population."(p. 55)

For more information, see:

Punch, J.L. & James, R.R. (2016), Wind turbine noise and human health: a four-decade history of evidence that wind turbines pose risks. Available from: *http://hearinghealthmatters.org/journalresearchposters/files/2016/09/16-10-21-Wind-Turbine-Noise-Post-Publication-Manuscript-HHTM-Punch-James.pdf*

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