Effects of Wind Turbine Noise on Human Health

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Huron County, Michigan (2009): First Wind Turbine Experience

- Multiple turbines surrounded residence; nearest was ~1,300 feet
- Family of four was leaving home at night to sleep in motel when turbines were operating
- Heard periodic whooshing sounds from several nearby turbines
- Felt momentary, mild sensations when turbines were operating
- Observed water rippling inside a bowl in the kitchen when turbines operated (apparently due to infrasound and low-frequency noise, or ILFN)

- Left the home feeling skeptical that wind turbines could cause serious sleep disturbance

Follow-Up to Huron County Experience

- Following literature review, co-authored an article in *Audiology Today*, an invited three-part blog, and a comprehensive review article (Punch & James, 2016), each on the effects of wind turbine noise (WTN) on health
- Chaired Michigan Wind and Health Technical Work Group to revise siting guidelines for onshore wind turbines in the state
- Served as expert witness in legal actions in multiple states, several of which involved interviewing affected residents
- Viewpoint: Noise from large wind turbines causes annoyance, a variety of unpleasant sensations, and adverse health effects (AHEs) in a substantial number of exposed people; view best described *not* as pro-wind or anti-wind, but as pro-health

Punch and James (2016)

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 at:

http://hearinghealthmatters.org/journalresearchposters/files/2016/09/16-10-21-Wind-Turbine-Noise-Post-Publication-Manuscript-HHTM-Punch-James.pdf

Wind Industry Talking Points Refuted by Punch and James (2016)

"Our review is organized by summarizing the past and present literature that addresses each of 12 selected statements, listed below, that encapsulate specific claims, or positions, commonly taken by advocates for the wind industry:

1. Infrasound is not an issue, as infrasound generated by wind turbines is not perceptible to humans.
2. There is nothing unique about wind turbine noise, as infrasound and low-frequency noise are commonly produced by the body and by many environmental sources.
3. There is no evidence that wind turbine noise, audible or inaudible, is the cause of adverse health effects in people, and there are no physiological mechanisms to explain how inaudible acoustic energy can be harmful.
4. Setback distances of 1,000-1,500 ft. (approximately 0.3-0.5 km) are sufficiently safe to protect humans from harm, regardless of height or other physical characteristics of the IWTs.
5. Annoyance is a nuisance, but it is not a health issue.
6. Noise cannot account for all of the complaints of people living in the vicinity of wind turbines; there must be another, unknown reason for the complaints.

Wind Industry Talking Points Refuted by Punch and James (2016, Cont.)

7. Infrasound from wind turbines is sufficiently correlated to the A-weighted sound emissions to allow an A-weighted model to be used to predict how much infrasound is present in homes.
8. Wind Turbine Syndrome has not been accepted as a diagnostic entity by the medical profession, so medical professionals cannot diagnose or treat it.
9. Peer-reviewed epidemiological literature is the only acceptable basis for proving a causative relationship between wind turbine noise and adverse health effects.
10. The nocebo effect, a manifestation of psychological expectations, explains why people complain of adverse health effects when living near wind turbines.
11. Only relatively few people, if any, are adversely impacted by wind turbine noise, and the majority have no complaints.
12. There is no evidence in the literature to support a causative link between wind turbine noise and adverse effects."

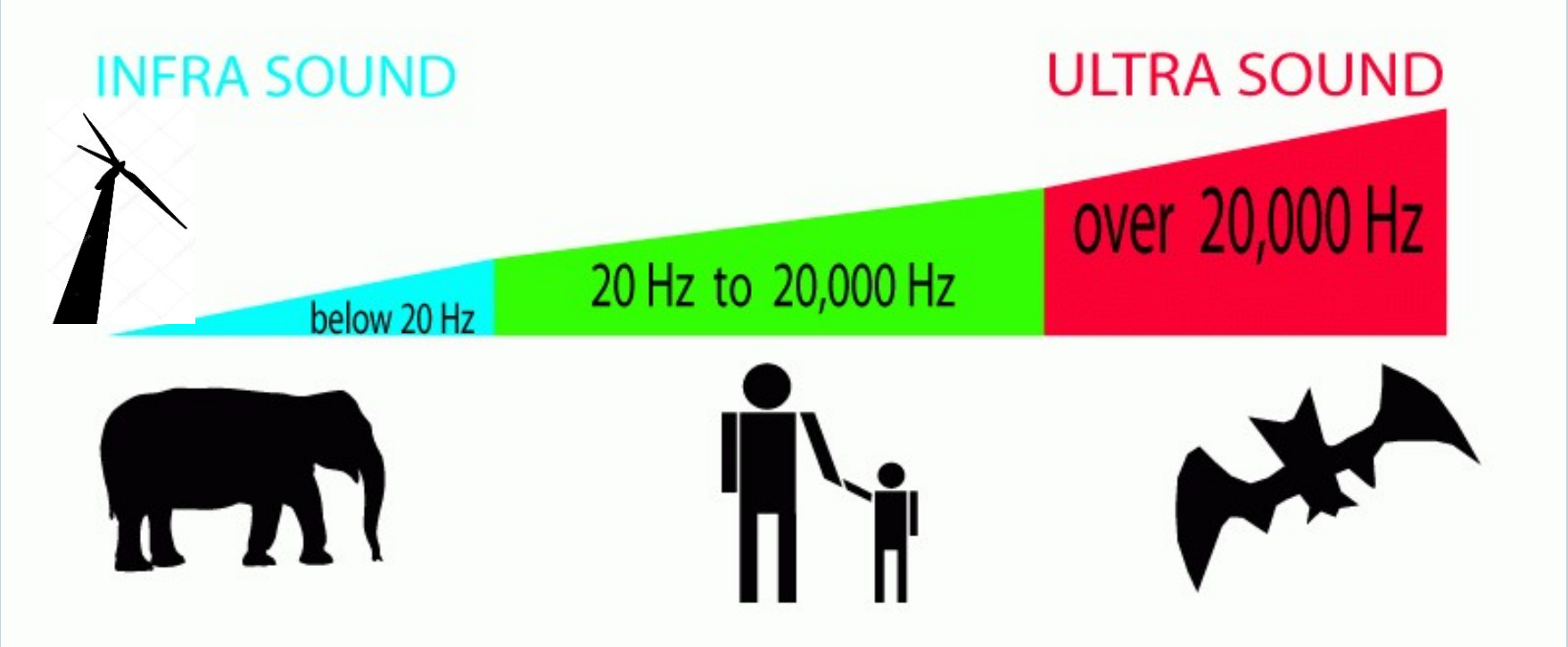
Assertion 1

Wind turbine noise is unique among industrial noises that are known to lead to high annoyance and AHEs.

- Amplitude-modulated ("whooshing noise")
- Impulsive (pressure pulses)
- Tones from blades, drive train and support equipment
- Perception varies with distance, terrain, wind direction
- Unpredictable (intermittent)
- Uncontrollable by receptors
- Occurs most often against low background noise levels in rural areas at night, disturbing sleep
- ILFN easily crosses property boundaries and penetrates homes and barriers

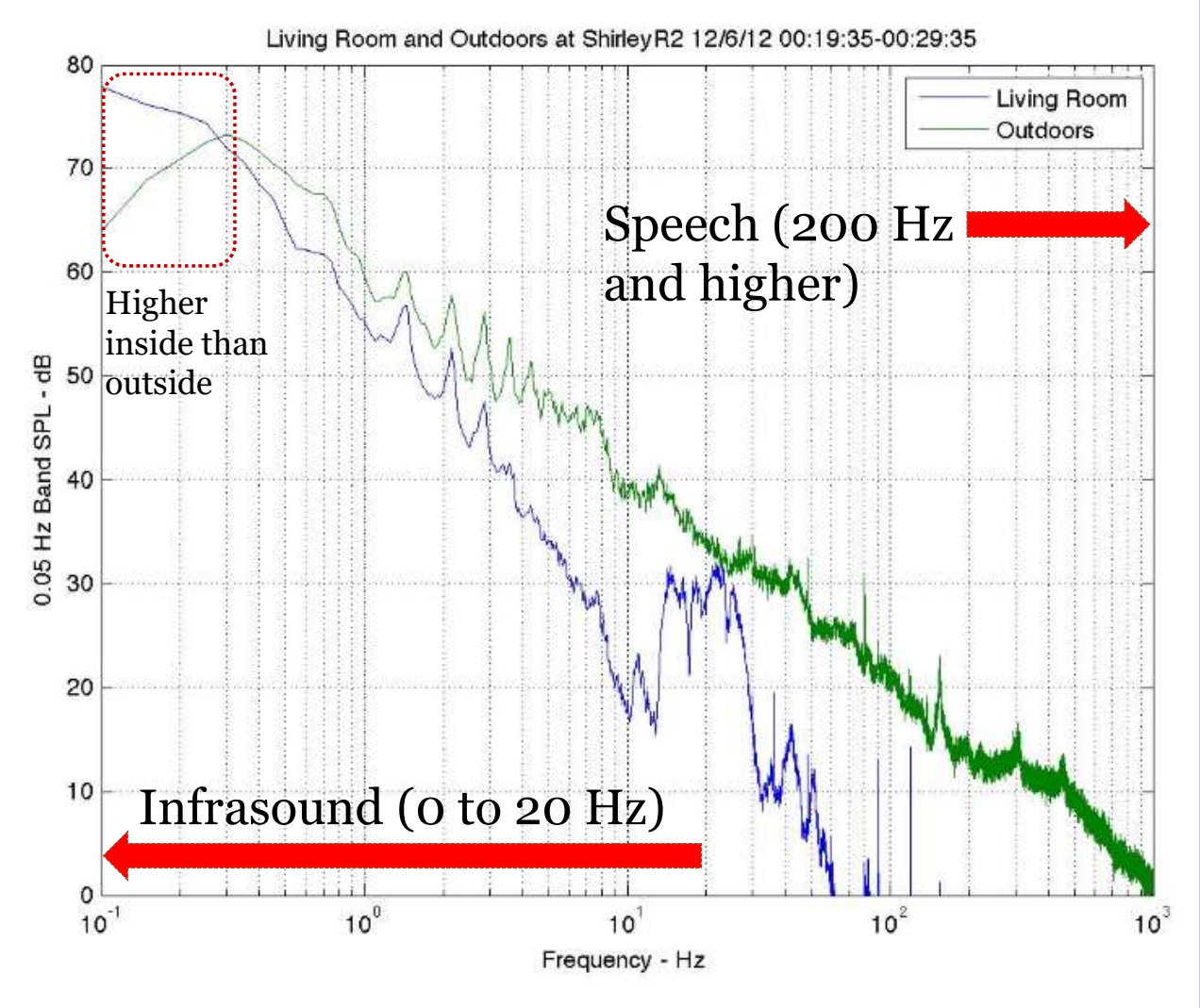
Taken together, these characteristics make WTN unique among transportation and other industrial noises.

Range of Human Hearing (20-20,000 Hz)



WTN contains both audible sound and infrasound. Infrasound can't be heard by most humans, but it can be perceived as abnormal (felt) sensations due to vibrations to bodily organs and tissues. It can become intensified inside closed spaces like homes.

Spectrum of Wind Turbine Noise: Outside vs. Inside



Assertion 2

Annoyance is an adverse health effect.

- WHO 1999 – current
  - (Berglund et al., Guidelines for Community Noise. World Health Organization, April 1999, 19-20)
- EPA (1972 – current)
  - (Noise Control Act of 1972 and others)
- Health Canada (current)
  - Considers high annoyance to be an (indirect) adverse health effect

Assertion 3

Many AHEs have been associated with audible and inaudible wind turbine noise, sleep disturbance being the most common complaint. Pressure pulses at infrasonic rates have been linked *directly* to negative sensations and AHEs.

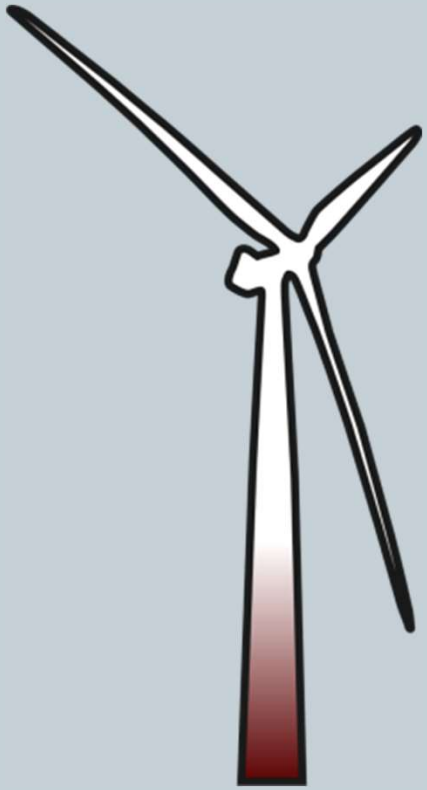
These effects, alone or in a variety of combinations, can occur in exposed individuals.

- Annoyance
- Sleep disturbance
- Headache
- Dizziness
- Vertigo
- Nausea (and other unpleasant bodily sensations)
- Motion sickness
- Tinnitus (ringing in ear)
- Fatigue
- Stress
- Depression
- Memory deficits
- Inability to concentrate
- Reduced quality of life
- Blurred vision (?)

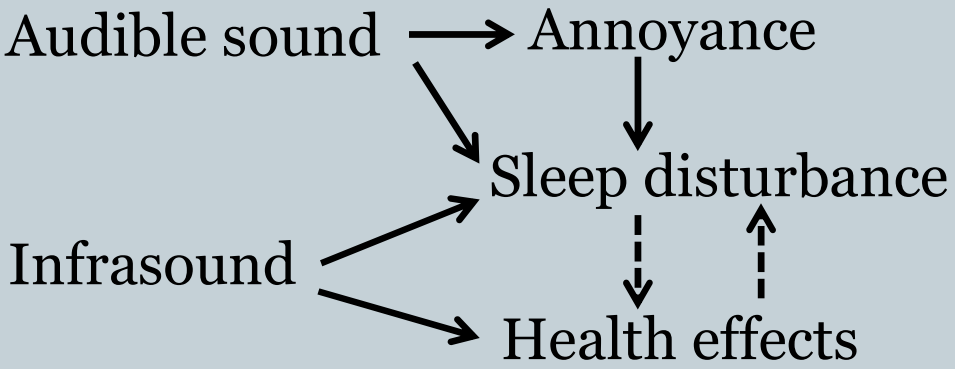
Medical Recognition of Health Impact of Infrasound

- The wind industry argues that medical professionals cannot diagnose or treat *Wind Turbine Syndrome* (Pierpoint, 2009) because it has not been accepted as a diagnostic entity by the medical profession.
- Virtually every human disease is associated worldwide with an ICD (International Classification of Diseases) diagnostic code for purposes of tracking medical conditions of individuals and populations.
- Although there is no ICD code specifically for "Wind Turbine Syndrome," codes exist for 8 of the 10 conditions identified by Pierpont.
- Recently, a new ICD code, *2022 ICD-10-CM Diagnosis Code T75.23XD,* was added to identify vertigo from infrasound.

Effects of Audible Noise and Infrasound on Health: Schomer (Modified)



Stress is often a mediator between stimulus and response.



Example: WTN can cause awakenings, and chronic awakenings can lead to AHEs.

→ Direct pathway

⇢ Indirect pathway

Observations from Personal Interviews: Individual Resident, Site A

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	✓

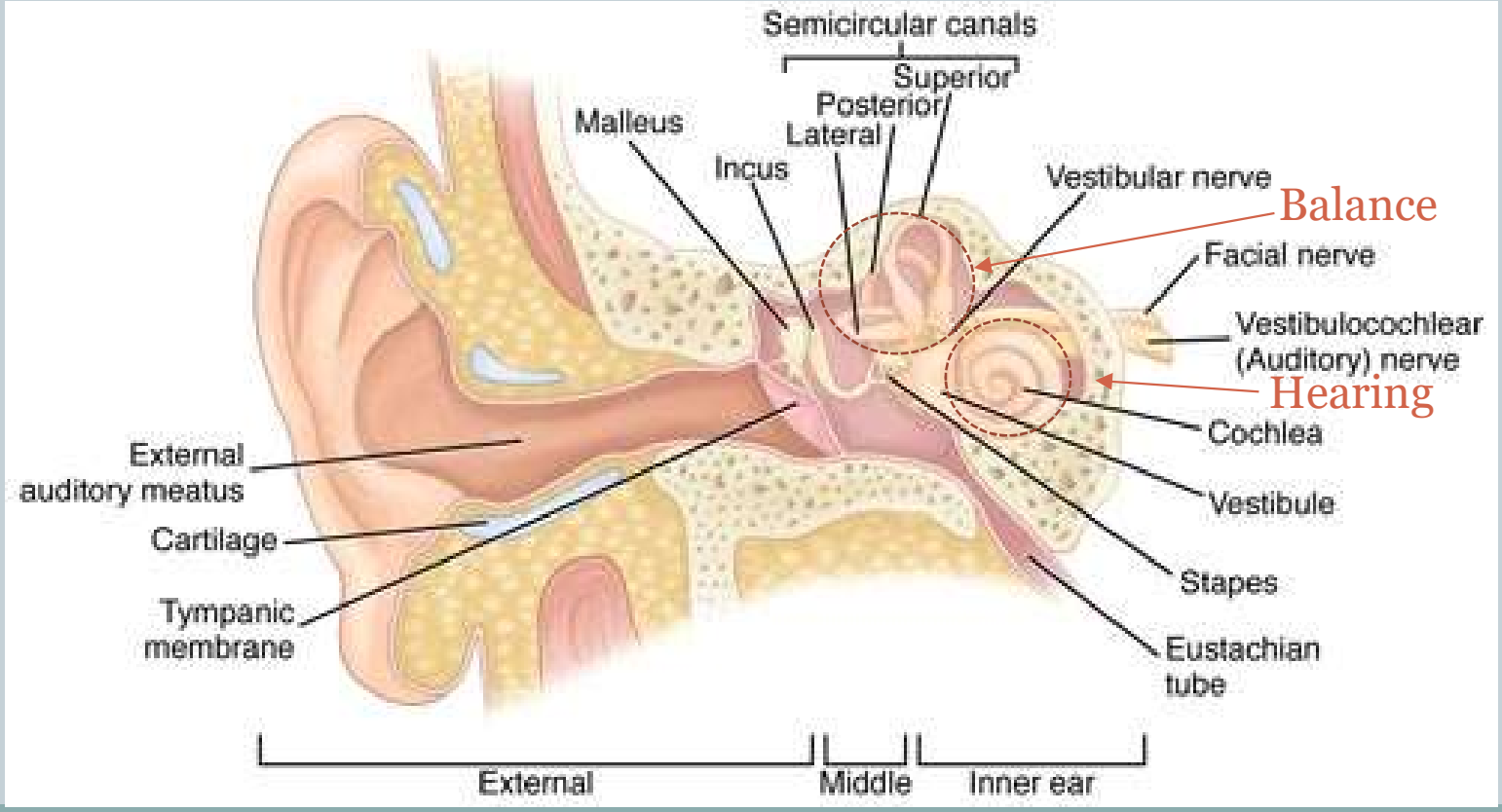
Observations from Personal Interviews: Family, Site B

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	✓	✓	✓

Assertion 4

Among other bodily organs responsible for negative reactions to wind turbine noise, both the cochlear and vestibular portions of the inner ear play major roles.



Motion Sickness

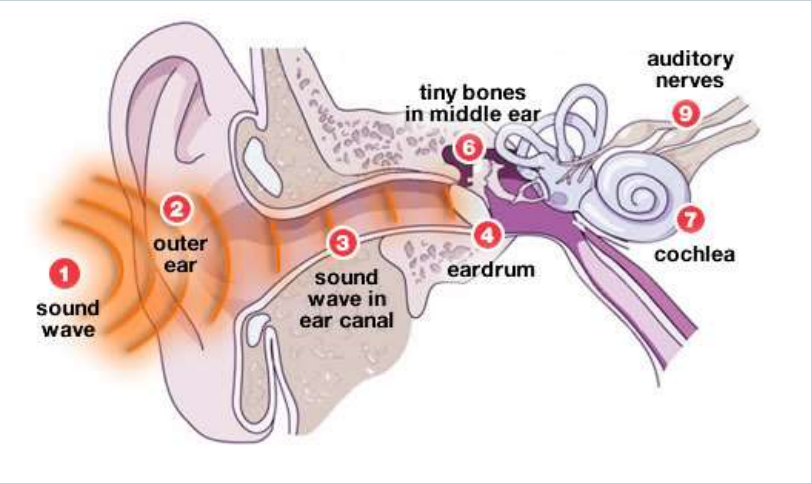
- Motion sickness can occur with wind turbine noise exposure because the infrasound and low-frequency noise can stimulate the fluid in the vestibular sense of balance, in much the same way as turbine noise can cause ripples in a container of water.
- Motion sickness occurs when stimulation to the inner ear's *vestibular system*, *visual system*, and *muscle stretch receptors* are in conflict.

Motion Sickness: Example

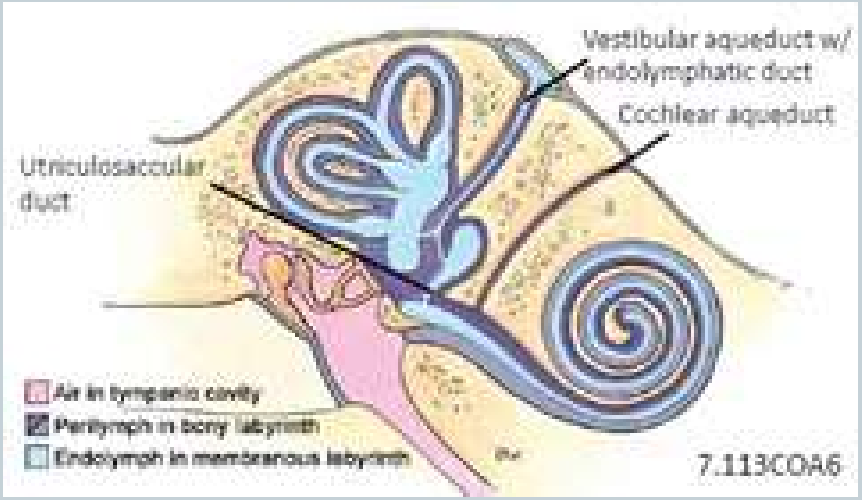
A person standing on a moving ferry boat and looking at structures inside the boat, such as the floor, cannot see any movement, and may feel minimal muscular stimulation, but the fluids in the vestibular system are being stimulated by the boat's slow, rocking movement in the water—resulting in motion sickness due to sensory conflict.

Assertion 5

Infrasound from external sources like IWTs is not processed in the same way as internally generated sounds like heartbeats.



Pathway of external sounds



Pathway of external sounds

Source: Salt, A.N. (September 18, 2013). Letter to Chairman of Association of Australian Acoustical Consultants. Available from: https://s3.amazonaws.com/windaction/attachments/1998/Warpenius.pdf.

Perception of Wind Turbine Infrasound (Cooper, 2014)

Australian acoustician Steven Cooper conducted a controlled, visually blinded, field study in cooperation with the wind company, Cape Bridgewater.

(1) WTN has a distinctive "signature" that is unlike a natural environment,

(2) Inaudible pressure pulsations from wind turbines, occurring at infrasonic rates, caused unpleasant perceptible "sensations" that were synchronized with wind turbine operations (on, ramping up-and-down), and

(3) Sensations included headache; pressure in the head, ears, or chest; ringing in the ears; heart racing; or a sensation of heaviness.

Perception of Wind Turbine Infrasound (Cooper & Chan, 2017)

In a separate laboratory experiment, Cooper and Chan showed that persons who experienced these "sensations" (and thus sensitized to low-frequency noise) were able to perceive WTN when exposed to it in a laboratory setting.

(1) Sensations were strongest when the entire body was exposed to WTN delivered through stereophonic loudspeakers (mimicking real life) when compared to hearing under headphones, and

(2) Results refute alternative explanations of AHEs, such as the so-called *nocebo effect*, by establishing a direct cause-effect relationship between infrasound and these negative effects.

Assertion 6

To protect health, limiting noise levels is more effective than establishing setbacks, especially the relatively short setbacks typically used.

- A 1.25-mile (2 km) setback has most often been recommended to minimize annoyance and AHEs. Some scientists and regulatory bodies are now recommending even longer setbacks to reduce health risks, especially given the increasing rated capacity of IWTs.
- The 1-mile setback proposed in the current Senate Bill 353 is reasonable, and worthy of support, especially when coupled with its requirement to limit WTN to 35 dB LAF(max).
- Limiting maximum noise levels is critically important during nighttime hours, as it protects the greatest number of residents from sleep disturbance.

Assertion 7

To protect health, nighttime wind turbine noise levels must be limited to no more than 10 dB above background levels.

- Background levels should be defined as those present during the quietest nighttime periods, with intermittent sounds such as traffic and wildlife noises excluded. Noise monitoring should be accompanied by sound recordings that allow identification and exclusion of those extraneous sounds from analysis. Rural areas have background sound levels of 20-25 dBA. This has been proven many times.
- The NY Department of Environmental Conservation (Table B) has determined that noise levels that exceed background levels by more than 10 dB will be associated with substantial resident complaints and increased AHEs.

Table B

HUMAN REACTION TO INCREASES IN SOUND PRESSURE LEVEL

Increase in Sound Pressure (dB)	Human Reaction
Under 5	Unnoticed to tolerable
5 - 10	Intrusive
10 - 15	Very noticeable
15 - 20	Objectionable
Over 20	Very objectionable to intolerable

(Down and Stocks - 1978)

Assertion 8

The wind industry wants regulations that use averaged noise levels (dBA Leq) to specify the amplitude of wind turbine noise, but Leq levels do not protect from exposure to sudden spikes in WTN (often 10-12 dB higher than the average level), which lead to high annoyance, sleep disturbance, and other AHEs.

- dBA Leq filters out *substantial* amounts of ILFN (50+ dB below 20 Hz).
- Leq measurements have most often been applied to transportation noise and industrial noises whose characteristics are different from IWTs.
- If averaged levels are used to limit nighttime noise, the most authoritative sources of noise guidelines recommend limiting the levels to 36-40 dB Laeq; those limits are preferably applied at property lines.
- Dr. Paul Schomer, Director Emeritus of the Standards Division of the Acoustical Society of America, has suggested that when dBA Leq is used to limit wind turbine noise, it is based on a goal of limiting *high annoyance* to 10% in the affected population. It does not limit pressure pulses to protect those who are sensitive.

Assertion 9

LAF(max), as opposed to the long-term average noise levels commonly advocated by the wind industry, is recommended to minimize sleep disturbance.

- The use of LAF(max) provides reasonable assurance that the levels of short-term, pulsating, nighttime wind turbine noise are sufficiently low to prevent serious AHEs.

dB LAF(max)

- Because energy peaks in noise are the major cause of sleep disturbance, the WHO has proposed that LAmax be used as an effective metric to minimize sleep disruption.
- WHO (Berglund et al., 1999; community noise)
  - 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)
  - Nighttime noise(inside) should be limited to 42 dB LAmax.
- Required maximum levels should be lower to account for the unique characteristics of WTN, which include high levels of ILFN.

Assertion 10

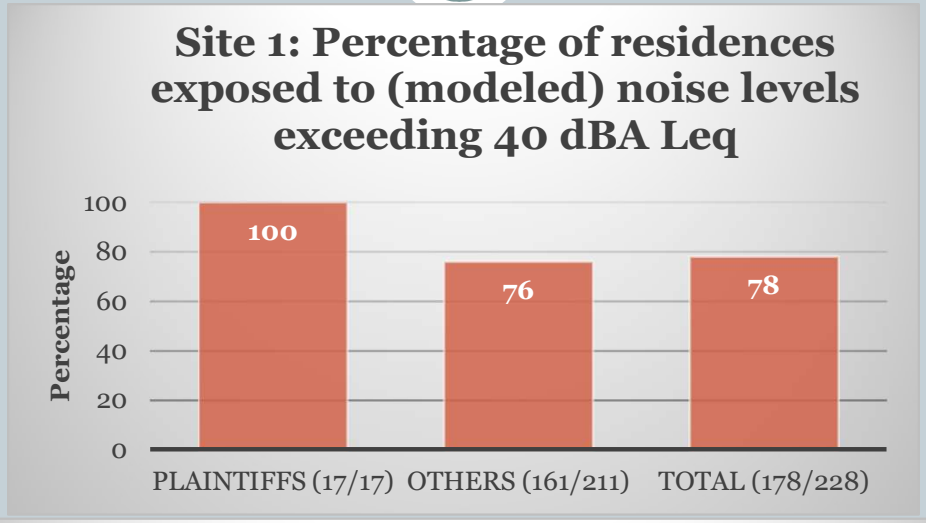
Although peer-reviewed epidemiological research is highly desirable in establishing a causative relationship between wind turbine noise and adverse health effects, it is not the only type of information that is helpful.

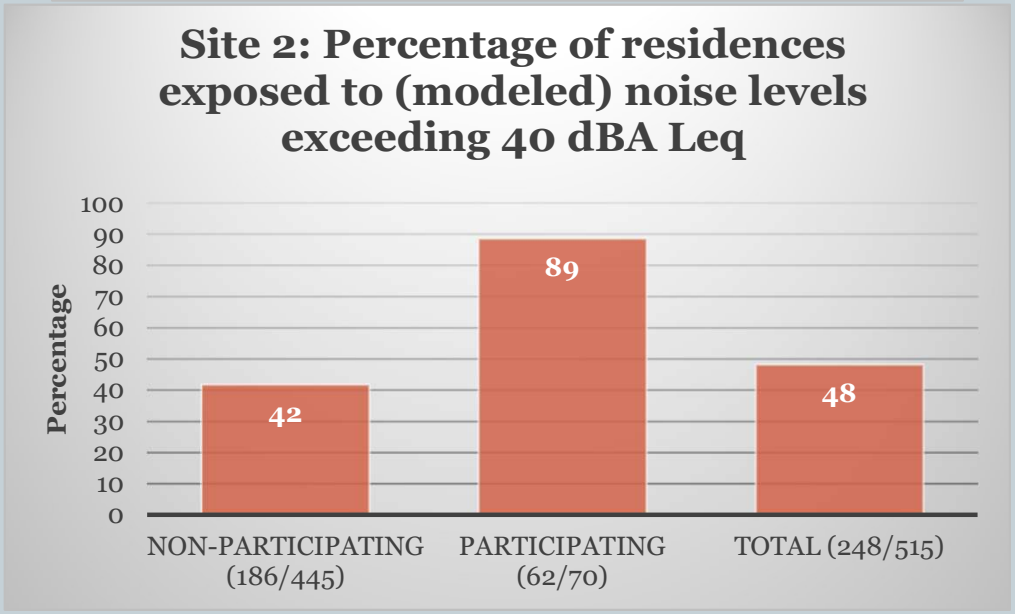
- Other types of helpful information include:
  - Anecdotal reports
  - News accounts (print and web-based media)
  - Documentary films
  - Legal proceedings
  - Reports by other scientists and professionals in peer-reviewed journals and at professional and society meetings, government reports, and internet postings
- (Refer to 1965 “Bradford Hill criteria” for determining causation.)

Recommended Setbacks and Noise Levels

- Setback Distance: Minimum distances ranging from 0.5-2.5 miles are often recommended to protect health. Setbacks recommended most often by researchers is 1.25 mi (2 km), but some now recommend longer setbacks. Property lines, not residences, should be used as targets for setbacks.
- Noise levels: When using A-weighting, recommendations include maximum levels ranging from 35-40 dBA. Some local zoning ordinances require noise levels be limited to 5-10 dB above prevailing background noise levels, with emphasis on nighttime levels, and some now include LAF(max).
- Case in point: Prompted by input from cardiologist Dr. Ben Johnson, the Madison County, Iowa, Board of Health recently incorporated 1.5-mile setbacks from property lines AND noise limits of 40 dBA Lmax and 60 dBC Lmax into its wind ordinance, which is currently being litigated.

Noise Analyses



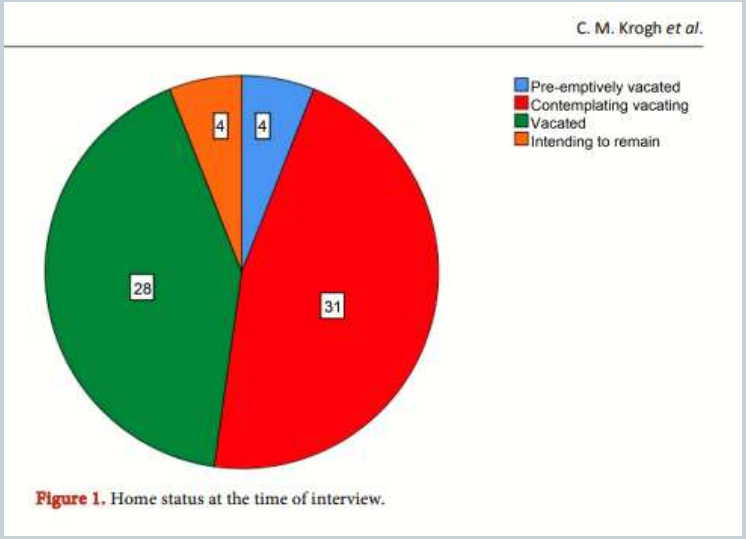


If IWTs Don't Harm People, Why Are Some Residents Abandoning Their Homes?

- There are numerous anecdotal reports worldwide.
- Carmen Krogh and colleagues currently are systematically studying motivations for home abandonment by families who lived near wind turbine facilities in Ontario, Canada, between 2006 and 2016.
- The research team acquired government records documenting that neighbors living near IWT facilities filed 4,574 noise complaints and/or incident reports related to the turbines.
- The team interviewed a sample of 67 participants, all reporting AHEs or potential for AHEs when living within 10 km (6.2 miles) of a wind project.

If IWTs Don't Harm People, Why Are Some Residents Abandoning Their Homes? (Cont.)

- Some temporarily left during the day and/or night to alleviate effects. At the time of the interviews, 4 (6%) had preemptively vacated their homes, 28 (42%) had permanently vacated, 31 (46%) were contemplating vacating, and only 4 (6%) intended to remain in their homes.



Krogh, C.M, McMurtry, R.Y., Dumbrille, A., Hughes, D., & Gillis, L. (2020). Preliminary results: exploring why some families living in proximity to wind turbine facilities contemplate vacating their homes—a community-based study. Open Access Library Journal, 7, doi: 10.4236/oalib.1106118.

- Decisions to abandon reflected concerns with physical, psychological, and social well-being; electrical fields; wind turbine noise, vibration, atmospherics, and wind conditions; pets and animals; well water disruption; and personal viewpoints, social justice, safety, and security.

Conclusions: Summary of Assertions

1. Wind turbine noise is unique among industrial noises that are known to lead to high annoyance and AHEs.
2. Annoyance is an adverse health effect.
3. Many AHEs have been associated with audible and inaudible wind turbine noise, sleep disturbance being the most common complaint. Pressure pulses at infrasonic rates have been linked *directly* to negative sensations and AHEs.
4. Among other bodily organs responsible for negative reactions to wind turbine noise, both the cochlear and vestibular portions of the inner ear play major roles.

Conclusions: Summary of Assertions (Cont.)

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7. To protect health, nighttime wind turbine noise levels must be limited to no more than 10 dB above background levels.

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Contact Information

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