

Wind Turbines and Health

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Background

- Internist and Occupational/environmental physician with experience in occupational noise exposure:
 1. Hearing loss assessment (review of audiometric tests)
 2. Development of OSHA Hearing Conservation Programs in industry
 3. Author of 3 book chapters and lecturer @ Harvard Residency Program on “Noise and Health”
- AWAE/CanWEA expert panel member



Point of Presentation: Address 3 main questions



Wind Turbines and Health

1. Is there sufficient scientific evidence to conclude that wind turbines adversely affect human health?
2. Is there sufficient scientific evidence to conclude that psychological stress, annoyance and sleep disturbance occur as a result of living near wind turbines? Do these effects lead to adverse health effects?
3. Is there evidence to suggest that infrasound and low frequency from wind turbines have unique potential health effects not associated with other sources of environmental noise?



What is the environmental “exposure” of concern with wind turbines?

- The main potential hazardous exposure from living near wind turbines is noise, however, concerns have also been raised about components of sound (i.e. infrasound, low frequency sound), EMF and shadow flicker



Do wind turbines affect health?

How to answer the question: a systematic review of the scientific literature

- Epidemiology Studies
- Experimental Studies
- Noise Assessments

Focus: effect of an exposure (noise) on health



Do wind turbines affect health?

Epidemiology Studies: Rich literature on environmental noise on human health dating to the 1970s

- Occupational Noise Exposure
- Environmental Noise Exposure-airports, highways, rail yards, construction
- Wind Turbines and Health

Experimental: infra sound on health



Methods

- PUBMED Search on key terms

Identified studies were categorized as follows:

1. Sound, its components and field measurements conducted in the vicinity of wind turbines
2. Epidemiology Studies of people living near turbines
3. Effects of sound components (infrasound and low frequency) sound on health
4. Psychological factors associated with responses to wind turbines
5. Governmental and non-governmental reports



Background to topic



Wind turbine syndrome – a popular topic online



“Wind turbine syndrome”

(nearly 300,000 Google hits (Sept 05, '14),
but only 3 PubMed references to this
specific “Search Term”

- **Self-published** book by Nina Pierpont (pediatrician)
- Telephone interviews of 10 **self-selected** families (23 people)
- Case series with **self-reported** data
- No medical exams; no diagnostic studies; no review of medical records; no noise measurements



“WT syndrome” (Pierpont 2009)

Non-specific symptoms included:

- ↓↓Concentration/memory
- ↓↓Motivation
- ↓↓Energy
- Anxiety
- Headache
- Panic attack
- Sleep disturbance
- Tinnitus
- Other ear symptoms
- Dizziness/vertigo
- Nausea
- Although subjects could all hear the WTs, Pierpont suggested that *symptoms were mediated by vestibular or visceral response to inaudible infrasound*



I. Sound and its components



Noise Levels in decibels (dBA**)

- Jet Engines 140
- Rock Band 110
- Tractor/power saw 100
- Lawn mower at 3 feet 95
- Vacuum cleaner at 3 feet 85
- Busy restaurant 78
- Speech range: 50-70
- Whisper 30
- **Area near wind turbine (300 meters)-35-45***

* See Environmental Impacts of Wind Energy Projects, NRC (2007)

- ***Risk of hearing impairment: exposure > 80 dB (A) for many years***





Sound Frequencies and Hearing

- Speech frequency 500 Hz -20,000 Hz
- Low frequency: 20-250 Hz
- Infra sound < 20 Hz



Sound Frequencies and Wind Turbines

Three kinds of sound emitted by wind turbines have received some attention are:

1. Infrasound
2. Low frequency sound of approximately 10-200 Hz
3. Fluctuating aerodynamic “swish” from the turbine blades which is in the mid-frequency range, approximately 500-1000 Hz.



“Whooshing” at blade-pass frequency (≈ 1 Hz)
is amplitude modulation, *not* infrasound)



WT Noise Measurements

- Measurements of low frequency sound, infrasound, tonal sound emission, and amplitude modulated sound
- Infrasound is emitted by wind turbines, but levels at customary distances to homes are below audibility thresholds, even at residences where complaints have been raised.



WT Noise Measurements

- A Canadian report investigated noise-related complaints at wind farms in Alberta, Canada over its entire history of wind power.
- Some turbines had been in operation for 20 years.
- Five (5) noise-oriented complaints at utility-scale wind farms were reported. None were repeated after the complaints were addressed.



II. Epidemiology Studies



Types of human studies that evaluate links between exposure to a hazard and an adverse health effect

- Longitudinal-move forward in time
- Retrospective-look back in time
- Case Control-evaluate cases of disease in comparison to control group
- **Cross sectional-evaluate exposure and disease at one point in time**
- Case series-a series of cases
- Case reports-one case

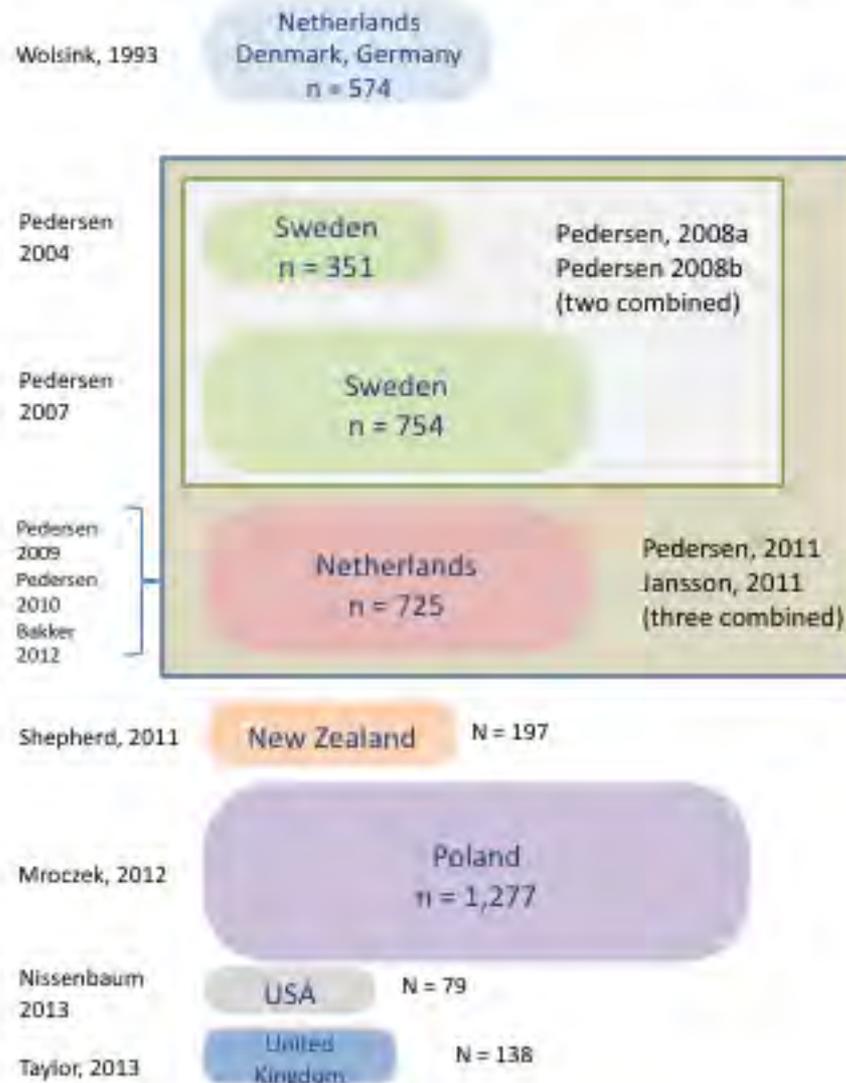


Types of peer reviewed studies related to wind turbines

- Epidemiology-all cross sectional studies
- Experimental-some placebo controlled studies related to infra sound
- Exposure assessments in vicinity of wind farms



Figure B-1: Relative Size and Location of Study Groups



Pedersen 2011: Review of 3 earlier studies



Pedersen 2011: Review of 3 earlier studies

| Symptom | 1 | 2 | 3 |
|--------------------|------------------|------------------|------------------|
| Annoyance outdoors | 1.24 (1.13-1.36) | 1.14 (1.03-1.27) | 1.18 (1.12-1.24) |
| Annoyance indoors | 1.38 (1.20-1.57) | 1.42 (1.17-1.71) | 1.20 (1.13-1.27) |
| | | | |
| | | | |



Pedersen 2011: Review of 3 earlier studies

| Health Effect | ? Effect from Noise |
|-------------------------|-----------------------------|
| High blood pressure | No significant increase |
| Cardiovascular diseases | No significant increase |
| Tinnitus | Increased in 1 of 3 studies |
| Headache | No significant increase |
| Tiredness | No significant increase |
| Stressed | No significant increase |
| Irritable | No significant increase |



Pedersen 2011: Review of 3 earlier studies

| Health Effect | ? Effect from self reported annoyance outdoors |
|-------------------|--|
| Sleep disturbance | 3 of 3 studies |
| Tense | 3 of 3 studies |
| Irritable | 3 of 3 studies |



Epidemiology Summary

1. No consistent association between noise from wind turbines and any reported disease or indicator of harm to human health;
2. Attitude toward visual impact of wind turbines on the scenery, attitude toward wind turbines in general, personality characteristics, whether individuals benefit financially from the presence of wind turbines, and duration of time wind turbines have been in operation all have been correlated with self-reported annoyance; and
3. Annoyance does not correlate well or at all with objective sound measurements or calculated sound pressures.



Epidemiology Summary

- Sleep disturbance has been associated with sound pressures of $> 40-45$ Db, but not any other measure of health or well-being. Stress was associated with annoyance, but not with calculated sound pressures (Pedersen 2011).



Sleep and noise

World Health Organization:
“Nighttime Noise Guidelines” (2009)



World Health Organization

Night time noise guidelines : 2009

- An L_{night} , (outside) of 40 dB * should be the target for night noise to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly. $L_{night, outside}$ value of 55 dB is recommended as an interim target for the countries where the NNG cannot be achieved in the short term for various reasons.

* *annual average*



EFFECTS ON SLEEP 51

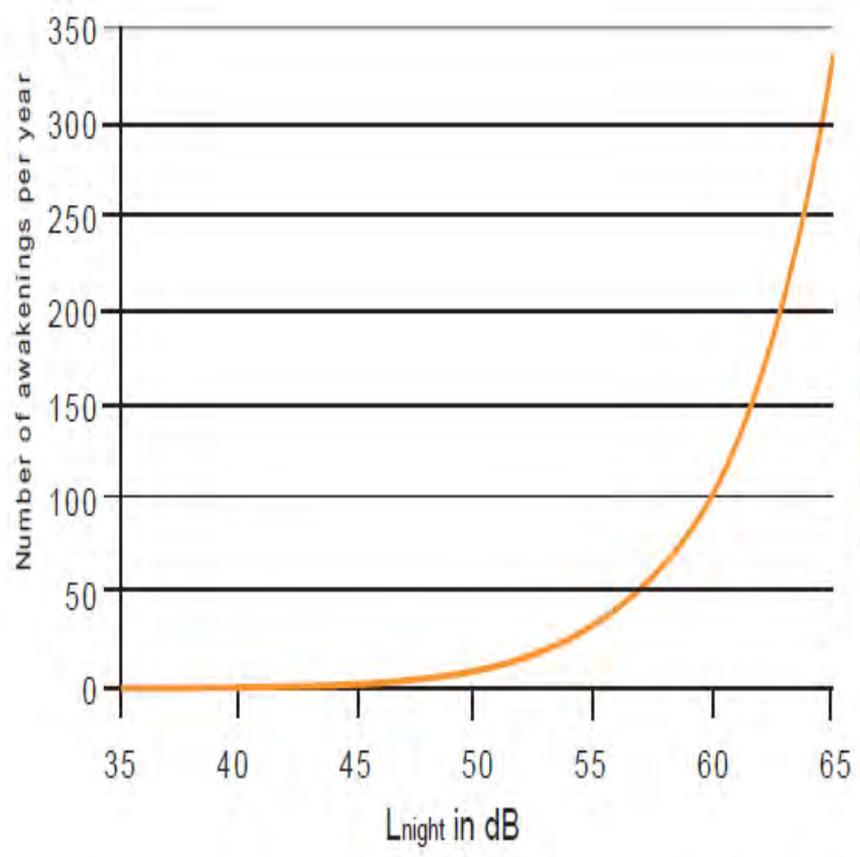


Fig. 3.1 Worst case prediction of noise-induced behavioural awakenings. L_{night}, converted from inside relation with [3] on page 10.

Source: Miedema, Passchier-Vermeer and Vos, 2003



Epidemiology Summary

Studies of quality of life (QOL) and proximity to wind turbines report conflicting findings:

- one study (with 38 participants living within 2.0 km of nearest wind turbine) reported lower health-related QOL among those living closer to wind turbines compared with respondents living farther away (Shepherd 2011),
- The largest of all studies (with 853 living within 1500 meters of the nearest wind turbine) found that those living closer to wind turbines reported higher quality of life and health than those living farther away (Mroczek, 2012).



Summary of wind turbine environmental studies

- A small percentage of people report being very annoyed by the sound from wind turbines at levels < 40 dB
- As noise levels increase, more people report being annoyed
- The perception of "annoyance" from the sound of wind turbines is strongly related to attitudes toward wind turbines more than the actual noise levels.



Wind Turbines and Health

- How about infrasound?
- How about low frequency sound?
- Is wind turbine noise different?



III. Sound components and health: infrasound, low frequency sound and potential health effects



Wind Turbine Sound and its components

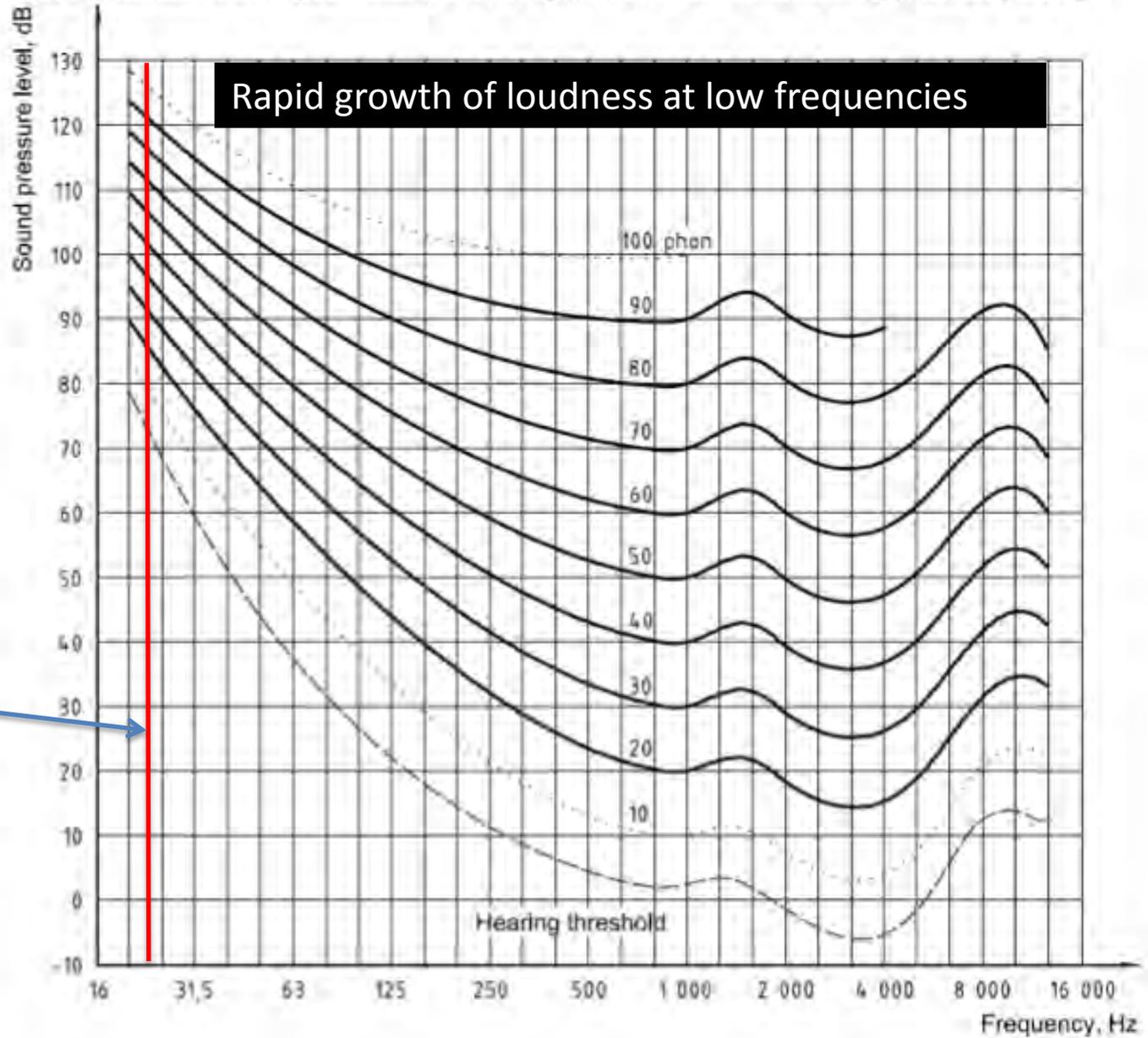
- Infrasound and low frequency sound can be generated by wind turbines; however, neither low frequency sound nor infrasound from wind turbines or in experimental studies have been associated with adverse health effects.



FIGURE 3-2

Hearing Contours for Equal Loudness Level (International Standards Organization, 2003)

26)



Arbitrary boundary 20 Hz



Infra sound

- Sources of infrasound include: cars, road traffic, aircraft, diesel engines, trains, refrigerators, household appliances, fans, compressors, pumps, music, TVs, air conditioning, etc.
- Other sources include sea waves , air turbulence, earthquakes and storms, sometimes thousands of miles away.



Infra sound and health

- Heart tones: 1-2 Hz
- Lung sounds: 5-35 dB at 150-600 Hz
- *“A few meters from the device, windmill noise in the infra sound range becomes rapidly inaudible. This infrasound has no effect on human health. Fears regarding windmill-induced infra sound are thus groundless. Infrasound production by windmills has been well studied and the levels are without risk to humans.” **

**Source: French National Academy of Medicine, 2006*



Property values can survive inaudible infrasound ...

Tour Leonardo DiCaprio's Malibu Home for Sale

Set in the star-studded Malibu Colony community, The Wolf of Wall Street actor's oceanfront compound offers three homes on one large lot. Take a peek inside Leonardo DiCaprio's beach retreat.

Sold for \$17.4 million –
despite surf infrasound > 75 dB SPL @ 25 m.
(Sonus Pty Ltd 2010; Turnbull 2012)



MS

Photo by: Zillow | [View Full Photo Detail](#)



Summary of infrasound and low-frequency sound as related to wind turbines

- Although wind turbines generate infrasound and low-frequency sound, detectable levels of infrasound and low-frequency sound are not at harmful levels based on studies in the USA, UK, the Netherlands, Denmark and Australia and ANSI Guidelines.
- No studies demonstrate harmful effects from exposure to infrasound or low-frequency sound at noise levels measured near residences near wind turbines or in experimental studies involving noise levels much higher than those noted in the vicinity of wind turbines



Low Frequency Sound and Health Effects

- Health effects of living in the vicinity of wind turbines and exposure to low frequency sound- evaluated in the Netherlands (van den Berg, 2008).
- No link between noise levels and risk of diabetes, hypertension, tinnitus and cardiovascular disease was noted.
- To the contrary, the illnesses assessed were more common at the lower sound levels than the higher sound levels.



Epilepsy and Wind Turbines

- At the time of preparation of this report, there has been no published report of a photo-epileptic seizure being triggered by looking at a rotating wind turbine.



IV. Annoyance, wind turbines and potential health implications



Annoyance, wind turbines and potential health implications

- Annoyance is a recognized health outcome measure used in studies of environmental noise for decades. Noise levels account for only a modest portion of self-reported annoyance in the context of wind turbines. (Knopper & Ollson, 2011).



Annoyance, wind turbines and potential health implications

- Noise sensitivity, a stable psychological trait, contributes equally to exposure in explaining annoyance levels ($r=0.37$).
- Annoyance associated with wind turbine noise shows a consistent small to medium adverse effect on self-rated quality of life and psychological wellbeing. Given the coarseness of measures employed in many studies, the magnitude of these findings are likely attenuated (Aguinis, Pierce, & Culpepper, 2009) and underestimate the impact of annoyance on quality of life.



Annoyance, wind turbines and potential health implications

- Visual impact increases annoyance beyond sound exposure and noise sensitivity, but at present there is insufficient research to conclude that visual impact operates separately from noise sensitivity, as the two variables are correlated. Wind turbine development is subject to the same global psychogenic health worries and nocebo reactions as other modern technologies (Rubin, 2014).



Annoyance, wind turbines and potential health implications

- Economic benefit mitigates the impact of wind turbine sound; however, research is needed to clarify the potential confounding role of (self) selection in this finding.
- Wind turbine development is subject to the same global psychogenic health worries and nocebo reactions as other modern technologies.
- The vast majority of findings reviewed in this section were correlational and therefore do not imply causality, and that other as unidentified factors may be associated with or responsible for these findings.



Nocebo effect

- Controlled lab evaluations support the notion that annoyance and other complaints may reflect, at least in part, preconceptions about the ability of wind turbine noise to harm health (Chapman 2013, Crichton 2013a, Crichton 2013b) or even the color of the turbine (Maffei 2013) more than the actual noise emission.



Nocebo response: how we worry ourselves sick

Many of us hope to find Wi-Fi wherever we go, preferably for free. But some people devote their lives to avoiding Wi-Fi altogether. Sufferers of Wi-Fi syndrome say that the radio waves used in mobile communication cause headaches, nausea, exhaustion, tingling, trouble concentrating, and gastrointestinal distress, among other symptoms. Some of the most afflicted take drastic action. According to the *Agence France-Presse*, one woman left her farmhouse in southeastern France after the arrival of mobile-phone masts (which, like Wi-Fi, use radio waves) and fled for a cave in the Alps. A handful of others have moved to

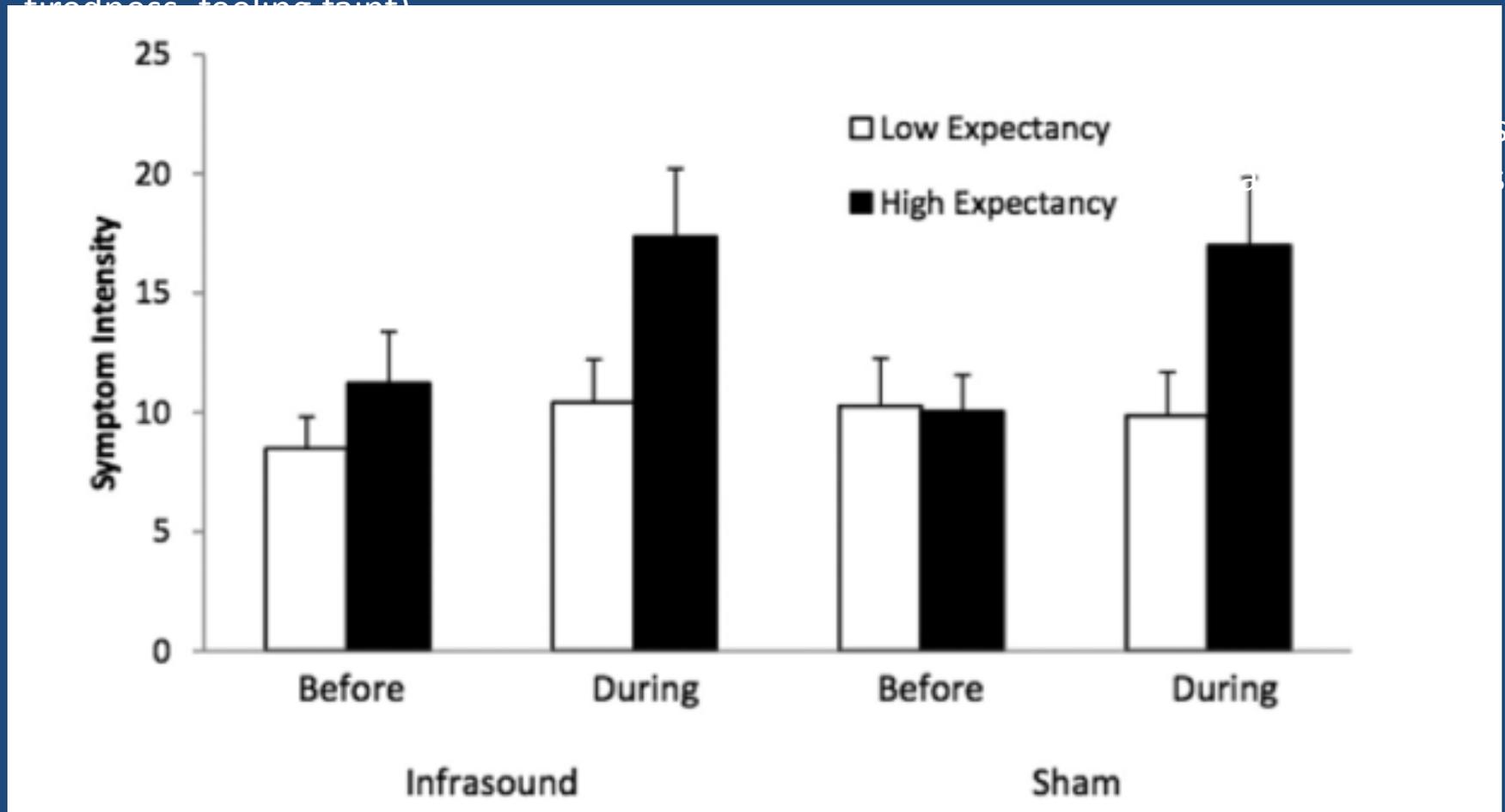


(New Yorker, 4/3/13)



Experimental proof of nocebo: Crichton et al 2013

(headache, ear pressure, ringing in the ears, itchy skin, sinus pressure or irritation, dizziness, pressure in the chest, vibrations within the body, racing heart, nausea, tiredness, feeling faint)



5 Hz, 40 dB SPL



WT symptoms: psychological mechanisms (Rubin, 2014)

- Nocebo – symptoms caused by expectation
- Misattribution of symptoms (new or pre-existing) to WTs, especially if disliked for other reasons
- Recall bias and hypervigilance (noticing and reporting more symptoms)
- Personality variables (coping, neuroticism, etc)



V. Government Reports



Massachusetts Department of Public Health Expert Panel report (2012)

- *“While annoyance as such is certainly not to be dismissed, in assessing global burden of disease the World Health Organization (WHO) has taken the approach of excluding annoyance as an outcome because it is not a formally defined health outcome per se.” (Concha-Barrientos et al., 2004).*



Massachusetts Department of Public Health (MDPH) Expert Report (2012)

- “There is insufficient evidence that the noise from wind turbines is *directly (i.e., independent from an effect on annoyance or sleep) causing health problems or disease.*
- There is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption.”



MDPH

- A dramatic finding of the Dutch study *:
- among people who benefited economically from the turbines (n=100; 14%)—who were much more commonly in the higher noise categories—there was virtually no annoyance (3%) despite the same pattern of noticing the noise as those who did not benefit economically. * (Pedersen et al, 2009)



MDPH

- *“Most epidemiologic literature on wind turbines relates to self-reported “annoyance,” which appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project.*
- *“There is no evidence for a set of health effects, from exposure to wind turbines that could be characterized as a “Wind Turbine Syndrome.”*



MDPH

- Typically, at distances larger than 400 m, sound pressure levels for modern wind turbines are less than 40 dB(A), which is below the level associated with annoyance in the epidemiological studies reviewed.



MDPH

- We conclude the weight of the evidence suggests no association between noise from wind turbines and measures of psychological distress or mental health problems.



NHMRC (Australia) 2014

- Expert panel of 5 university professors, 2 physicians and a consumer advocate
- Represented public health, epidemiology, sleep medicine, psychology, environmental health and acoustics



Australia (2014)

Selection of literature

- Studies needed to address exposure to wind farm emissions and not choose participants only because they had reported health effects
- Compare two or more groups with different levels of exposure to wind turbines (i.e. near and far)
- Report on health outcomes



NHMRC (Australia) Summary

- No reliable evidence that proximity to wind farms directly causes health effects
- Unlikely that wind farm noise would be heard > 500-1500 meters away
- “Wind farms unlikely to cause any direct health effects at distances more than 500 meters.”
- “At 500-1500 m, noise levels are in the range of 30-45 dBA-at these levels, effects on sleep are likely to be modest, if any.”



NHMRC (Australia) Summary

- “People exposed to infra sound and LFN in a lab at much higher levels than those near wind farms experience, few, if any, effects on body functioning.”



VI Discussion

Evaluating causal links between symptoms and living near wind turbines



Causality Assessment: Did exposure to a hazard cause an adverse health effect?

- Symptoms raised in context of wind turbines are common and have numerous causes
- Thorough medical evaluation to reach diagnosis is essential
- Careful consideration to exposure (i.e. noise levels) in light of literature.



Causality Assessment:

Caution in patient assessed causality

- Recall Bias may be a factor
- Alternative explanations need to be addressed (I.e. sleep, tinnitus, sleep disturbance all have multiple causes)



Future Research

- Noise Assessments
- Epidemiology
- Sound Components
- Annoyance



Summary of Review

1. Measurements of low frequency sound, infrasound, tonal sound emission, and amplitude-modulated sound show that infrasound is emitted by wind turbines. The levels of infrasound at customary distances to homes are typically well below audibility thresholds.
2. No cohort or case-control studies were located in this updated review. Among the cross-sectional studies of better quality, no clear or consistent association is seen between wind turbine noise and any reported disease or indicator of harm to human health.
3. Components of wind turbine sound, including infrasound and low frequency sound, have not been shown to present unique health risks to people living near wind turbines.
4. Annoyance associated with living near wind turbines is a complex phenomenon related to personal factors. Noise from turbines plays a minor role in comparison to other factors in leading people to report annoyance in the context of wind turbines.



Summary of Other Reviews



AWEA (2009); MDPH (2012) and NHMRC (2014) Conclusions

1. Noise from wind turbines does not pose a risk of hearing loss or any other direct adverse health effect.
2. Some people become annoyed from wind turbine sound
3. The major concern from wind turbine noise is its fluctuating nature. Some find this noise annoying, a reaction dependant primarily on personal characteristics as apposed to the intensity of the noise level.
4. Sub audible low frequency noise and infra sound from wind turbines do not present a risk to health.
5. Wind Turbine Syndrome is neither a new disease or accepted medical diagnosis. Symptoms reflect noise annoyance.

