

Suggested literature on the effects of low-frequency noise and vibration on humans / effects of industrial wind turbines on nearby residents

Prepared for Dr. Sarah Laurie, to be forwarded to the NHMRC

1. Prof. Dr. Detlef Krahe. **Why is sharp-limited low-frequency noise extremely annoying?**

Conference paper - Acoustics08 Paris. Link: <http://docs.wind-watch.org/Krahe-low-frequency-noise-annoying.pdf> ... an investigation into the neurological consequences of acoustic stimulation with LFN signals that show an “uneven” distribution of frequencies across their spectra...

2. Dr. K. Genuit. **Tiefe Frequenzen sind nicht gleich tiefe Frequenzen – Tieffrequente Geräuschanteile und deren (Lärm-)Wirkungen. (LFN does not equal LFN – LF components of sound and their effects (on man)).** HEAD acoustics GmbH. Conference paper – DAGA 2007. Link: http://www.head-acoustics.de/downloads/messen/DAGA_2007_Tiefe_Frequenzen_ge.pdf

...in my opinion one of the best papers on the real effects of long-term exposure with ILFN. The author clearly states: inaudible LFN (ILFN) has effects on man; most data available today was generated by short-time exposure but high sound pressure – therefore; most “numbers” we use in assessing the real effect of LFN on people are useless; time (duration of exposure) and frequency, as well as the distribution of frequencies in a noise signal are the key factors that determine if a sound has negative health effects or not.

3. Wayne KP, Bengtsson J, Kjellberg A, Benton S. **Low frequency noise "pollution" interferes with performance.** Noise Health [serial online] 2001 [cited 2012 Sep 4];4:33-49. Available from: <http://www.noiseandhealth.org/text.asp?2001/4/13/33/31803>

4. Chao P, Yeh C, Juang Y, Hu C, Chen C. **Effect of low frequency noise on the echocardiographic parameter E/A ratio.** Noise Health [serial online] 2012 [cited 2012 Sep 4];14:155-8. Available from: <http://www.noiseandhealth.org/text.asp?2012/14/59/155/99881>

...a paper dealing with high-level LFN, confirming the findings of Castelo-Branco and Alvez-Pereira! VAD-skeptics always questioned the existence of VAD, stating that no research group outside Portugal was able to confirm their findings... well, that's history now.

5. Findeis H, Peters E. **Disturbing effects of low frequency sound immissions and vibrations in residential buildings.** Noise Health [serial online] 2004 [cited 2012 Sep 4];6:29-35. Available from: <http://www.noiseandhealth.org/text.asp?2004/6/23/29/31665>

...hidden in the document quite a few relevant observations can be found, like people become sensitized over time, that the noise has an effect on their vestibular organs etc. “It is emphasised that in the frequency range above approximately 20 Hz there may occur, (...), highly disturbing effects even if the magnitude of the vibrations is distinctly below the perceptive threshold of humans. According to the observations as demonstrated, these immissions ought to be given special attention in the future.”

6. K. PERSSON WAYE, R. RYLANDER, **THE PREVALENCE OF ANNOYANCE AND EFFECTS AFTER LONG-TERM EXPOSURE TO LOW-FREQUENCY NOISE** - Journal of Sound and Vibration DOI:10.1006/jsvi.2000.3251. Department of Environmental Medicine, Göteborg University, 40530, Gothenburg, Sweden, Link: <http://www.sciencedirect.com/science/article/pii/S0022460X00932516>

... the “heat pump study” – pretty relevant in my opinion, as it has a look at the effects of long-term ILFN exposure on people.

7. Feldmann J, Pitten FA. **Effects of low frequency noise on man-a case study.** Noise Health [serial online] 2004 [cited 2012 Sep 4];7:23-8. Available from: <http://www.noiseandhealth.org/text.asp?2004/7/25/23/31650>

... the (in)famous case of Mr. and Mrs Bählkow, who live only a few yards from a micro-power station in that emits LFN at a level just barely below the perception threshold. The detailed description of the various physiological effects of the combined exposure to ILFN and vibration shows striking similarities to the increasing number of reports we get from residents living near wind turbines.

8. RKI – Germany. **Infraschall und tieffrequenter Schall – ein Thema für den umweltbezogenen Gesundheitsschutz in Deutschland? (Subsonic low frequency sound--a topic for the environmentally related health protection?** Report of the commission "Methods and Quality Assurance in Environmental Medicine) Link: http://edoc.rki.de/documents/rki_ab/re67fIHRghoUo/PDF/22wFEQ7q9U2VE.pdf

... a report (in German) from the German Robert-Koch-Institut (The Robert Koch Institute is a Federal Institute within the portfolio of the Federal Ministry of Health) clearly names IWTs as a significant source of IS/LFN that can lead to "annoyances" ... the medical explanations given are pretty dated though ("resonance" model of the body etc.)

9. Ising H, Lange-Asschenfeldt H, Moriske H, Born J, Eilts M. **Low frequency noise and stress : Bronchitis and cortisol in children exposed chronically to traffic noise and exhaust fumes.** Noise Health [serial online] 2004 [cited 2012 Sep 4];6:21-8. Available from: <http://www.noiseandhealth.org/text.asp?2004/6/23/21/31666>

...Quote: "High exposure to traffic noise, especially at night-time and with predominant low frequency spectra, is associated with enhanced activation of the hypothalamus-pituitary-adrenal (HPA) axis and this in turn leads in the long term to an aggravation of bronchitis in children."

10. Punch, James, Pabst; **Wind-Turbine Noise – What Audiologists Should Know**, Audiology Today, Jul/Aug Issue 2010. Link: <http://legalelectric.org/f/2010/07/rj-03-windturbinenoise-2010-july-aug-audiology-today.pdf> ...the article documents the effects of LFN from wind turbines on people in an understandable language.

11. Sennheiser GmbH* **The city and its secret vibrations** – Link: <http://www.sennheiser-annualreport.com/home/2011/index.php?page=schwingen&lang=en>

... editorial to 2011 annual report. Describes the effects (i.e. insomnia) of ILFN on people. Links the worldwide increase of a cluster of symptoms to man-made sources of low-frequency noise below the hearing threshold.

*: Sennheiser (German manufacturer of high-end microphones and professional audio equipment).

12. Todd, Neil. **Evidence for a behavioral significance of saccular acoustic sensitivity in humans.** The Journal of the Acoustical Society of America, Volume 110, Issue 1, July 2001, pp.380-390. ... In short, (low frequency) sound perceived (though not consciously) via the pathway of the sacculus does have a measurable effect on the behavior people...

13. C. Kasprzak. **The Influence of Infrasonds on the Electrocardiograph Patterns in Humans** - Department of Mechanics and Vibroacoustics, Faculty of Mechanical Engineering and Robotics AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland. Link: <http://przyrbwn.icm.edu.pl/APP/PDF/118/a118z1p20.pdf>

... basically a confirmation that LFN does influence ECG patterns. Yes, short-term, high-level LFN but we know from a lot of cases that exposure to LFN leads to an increased sensibility to acoustic LFN signals after 1-8 weeks.

14. Joseph Park and James Robertson. A portable infrasound generator, Infrasound Laboratory, University of Hawaii, 2009 Acoustical Society of America DOI: 10.1121/1.3093797 Link: http://jpark.us/pubs/JASA_125%284%29_PortableInfrasound_2009.pdf

... the document shows, how due to the low attenuation of the atmosphere at low frequencies, even a tiny “ventilator”-type LFN source can emit a signal powerful enough to be measured at a distance of 3.9km. Now consider how far the “noise signal” of an industrial wind turbine will travel. (50km, according to a German study from the 90s – recently confirmed by Italian geologists whose IS recordings have been ruined by wind turbines sited 26 km away).

15. Erin F. Baerwald, Genevieve H. D’Amours, Brandon J. Klug and Robert M.R. Barclay. Barotrauma is a significant cause of bat fatalities at wind turbines, Department of Biological Sciences, University of Calgary, Calgary, in: Current Biology Vol 18 No 16, 2008. Link: <http://www.batsandwind.org/pdf/baerwald%20et%20al%20current%20biology%202008.pdf>

...gives a clear picture of the huge atmospheric pressure changes near wind turbines (AKA infrasound) - enough to make bat’s lungs pop. Eliminates the myth that IWTs “do not emit infrasound at significant levels”.

16. Fabian Kamp, Roland Sottek, André Fiebig. Lautheitswahrnehmung von tieffrequenten Schallen (perception of loudness of low-frequency sounds) – in German, HEAD acoustics GmbH, DAGA 2012, conference paper. ... their research is showing that the various standards (ANSI S3.4-2007, DIN 45631/A1 und ISO 532 B) used for estimating the perceived loudness of noise don’t work well when a low-frequency component is present in the spectrum.

17. N. Pierpont MD PhD. Wind Turbine Syndrome and the Brain, conference paper, First Intl. Symposium on the Global Wind Industry and Adverse Health Effects: Loss of Social Justice?, Picton, Ontario, CN, Oct. 30, 2010 Link: <http://windturbinesyndrome.com/img/WTSbrain-BW.pdf>

...describes a very plausible link between ILFN exposure and the symptom cluster observed in people living next to wind development areas ... Symptoms described also match the large number of reports from cases of people exposed to other sources of low-level infrasound/LFN, such as heat pumps, ventilation systems, compressors or sewage pumps. One of the best papers available when it comes to develop an understanding why long-term, low-level LFN exposure is a serious health issue, no matter what the noise source might be.

18. C. Krogh, R. Jeffrey, J. Aramini, B. Corner. Wind turbine noise perception, pathways and effects: a case study, conference paper, InterNoise 2012. Link: <http://docs.windwatch.org/Krogh%20et%20al%20-%20Wind%20Turbines%20-%20Noise%20Perception%20and%20Health.pdf>

... a comprehensive, systematic collection of the real-life effects of long-term exposure to the noise from wind turbines.

19. N. Salt, T. Lichtenhan. Perception-based protection from low-frequency sounds may not be enough, Cochlear Fluids Research Laboratory, Washington University in St. Louis, conference paper, InterNoise – Aug. 2012. Link: <http://oto2.wustl.edu/cochlea/saltlichtenhaninternoise2012.pdf>

... “This study shows that it cannot be assumed that noise levels as low as 40 dB A are benign and do not cause strong stimulation of the ear. Low-frequency noise around 40 dB A undoubtedly affects the ear. If the noise consists of predominantly low frequencies, then it will induce greater stimulation of the ear than has hitherto been appreciated.” (and that’s just one of the rather disturbing insights presented in this exceptional document).

20. Salt, A.N. Acute endolymphatic hydrops generated by exposure of the ear to nontraumatic low frequency tone. JARO 5, 203-214 (2004). Link: <http://www.springerlink.com/content/6p7hnkr4gcbhaxq3/fulltext.pdf>

... This study simply busted the infrasound-myth of “what you can’t hear, can’t hurt you”...

21. Haruka Tamura, Nobutaka Ohgami, Ichiro Yajima, Machiko Iida, Kyoko Ohgami, Noriko Fujii, Hiroyuki Itabe, Tastuya Kusudo, Hitoshi Yamashita, Masashi Kato **Chronic Exposure to Low Frequency Noise at Moderate Levels Causes Impaired Balance in Mice**, (PLoS ONE: Research Article, published 29 Jun 2012 10.1371/journal.pone.0039807). Link: <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0039807>

... shows in a dramatic way what effect just 1 month of continuous exposure to LFN at moderate levels has on the vestibule (of lab animals) – matches the observations we make in humans (balance disorders) living close to industrial wind turbines.

22. Ogido R, Costa EA, Machado Hda C. **Prevalence of auditory and vestibular symptoms among workers exposed to occupational noise**, Departamento de Medicina Preventiva e Social, Faculdade de Ciências Médicas, Universidade Estadual de Campinas, Campinas, SP, Brazil. Rev Saude Publica. 2009 Apr;43(2):377-80. (Article in Portuguese) Link: <http://www.ncbi.nlm.nih.gov/pubmed/19287878>

... shows that noise in general does have an effect on the vestibular system in humans – a fact that was widely suspected but not proven in the 1990s (Hinchcliffe et al.).

23. Guest M, Boggess M, D'Este C, Attia J, Brown A. **An observed relationship between vestibular function and auditory thresholds in aircraft-maintenance workers**. School of Health Sciences, University of Newcastle, Australia, J Occup Environ Med. 2011 Feb;53(2):146-52. Link: <http://www.ncbi.nlm.nih.gov/pubmed/21270662>

...quote: "This study has demonstrated a relationship between low-frequency hearing loss (as a result of noise exposure), vestibular dysfunction, anxiety, and depression in an occupational population." The similarities to the cluster of seemingly unrelated symptoms we see in residents near wind farms (namely vestibular disorders, anxiety, depression) would warrant a closer look at this paper.

24. Grewal T, James C, Macefield VG. **Frequency-dependent modulation of muscle sympathetic nerve activity by sinusoidal galvanic vestibular stimulation in human subjects**, J Occup Environ Med. 2011 Feb;53(2):146-52. Link: <http://www.ncbi.nlm.nih.gov/pubmed/21270662>

...the implications from this paper are far-reaching: Sound is known to stimulate the vestibular "sensors" – combined with the findings of the authors, this could well mean that certain low-frequency sound patterns could in fact influence the MSNA rhythm...

25. Michael Nissenbaum MD, Jeff Aramini PhD, Chris Hanning MD. **Adverse health effects of industrial wind turbines: a preliminary report**, conference paper, 10th International Congress on Noise as a Public Health Problem (ICBEN) 2011, London, UK: Link: http://docs.wind-watch.org/Nissenbaum-et-al-ICBEN2011_0158_final.pdf

... quote from the study: "This study, which is the first controlled study of the effects of IWT noise on sleep and health, shows that those living within 1.4 km of IWT have suffered sleep disruption which is sufficiently severe as to affect their daytime functioning and mental health."

26. Pedersen E, Persson Waye K (2004). **Perception and annoyance due to wind turbine noise—a dose-response relationship**. Department of Environmental Medicine, Göteborg University, P.O. Box 414, SE-405 30 Göteborg, Sweden, in: J Acoust Soc Am 116: 3460–3470. Link: <http://www.proj6.turbo.pl/upload/file/263.pdf>

...the study shows that the noise from IWTs is perceived as dramatically more disturbing to most people as one would expect from db(A) levels alone:

27. Frey BJ, Hadden PJ (2007). **Noise radiation from wind turbines installed near homes**, Link: <http://www.psc.nd.gov/database/documents/08-0034/105-010.pdf>

... the report is a valuable collection of insights concerning the impact IWTs have on people in nearby homes. The authors conclude that a minimum distance between homes and wind turbines should be kept to 2km, more, if more than 2MW of power is installed.

28. Moller, Pedersen. Low Frequency Noise from Large Turbines, Section of Acoustics, Aalborg University, J Acoustical Society America 2011 129: 3727 - 3744 Link: <http://www.ncbi.nlm.nih.gov/pubmed/21682397>

...given the outstanding reputation of Moller as an Acoustician, his findings should be taken rather seriously. Quote: "If the installed nominal electric power is the same, large turbines affect a larger area with noise than small turbines do." And: "If the noise from the investigated large turbines has an outdoor A-weighted sound pressure level of 44 dB (the maximum of the Danish regulation for wind turbines), there is a risk that a substantial part of the residents will be annoyed by low-frequency noise even indoors."

29. Wolfgang Babish. Cardiovascular effects of noise, Editorial commentary, Noise Health 2011;13:201-4 Link: <http://www.noiseandhealth.org/text.asp?2011/13/52/201/80148>

...quotes: "It is well understood that noise levels below the hearing damaging criterion cause annoyance, sleep disturbance, cognitive impairment, physiological stress reactions, endocrine imbalance, and cardiovascular disorders." ... "The question at present is no longer whether noise causes cardiovascular effects, it is rather: what is the magnitude of the effect in terms of the exposure-response relationship (slope) and the onset or possible threshold (intercept) of the increase in risk."

30. McMurtry, Prof. Robert. Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis, Bulletin of Science Technology and Society 2011 31:316 Link: <http://bst.sagepub.com/content/31/4/316>

...quote from the abstract: "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."

31. Capuccio F. et al. Sleep Duration predicts cardiovascular outcomes: a systemic review and meta-analysis of prospective studies, *Eur Heart J*. 2011 Jun;32(12):1484-92. Epub 2011 Feb 7. Link: <http://www.ncbi.nlm.nih.gov/pubmed/21300732>

...quote: "...Short duration of sleep was associated with a greater risk of developing or dying of CHD (coronary heart disease) (RR 1.48, 95% CI 1.22-1.80, P < 0.0001), stroke (1.15, 1.00-1.31, P = 0.047),(...)" ...

32. Salt AN, Hullar TE. Responses of the ear to low frequency sounds, infrasound and wind turbines. Department of Otolaryngology, Washington University School of Medicine, *Hear Res*. 2010 Sep 1;268(1-2):12-21.Epub 2010 Jun16. Link: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2923251/>

...quote: "This raises the possibility that exposure to the infrasound component of wind turbine noise could influence the physiology of the ear"

33. Carl V. Philips. Properly Interpreting the Epidemiologic Evidence About the Health Effects of Industrial Wind Turbines on Nearby Residents, Populi Health Institute, Wayne, PA, USA, Bulletin of Science, Technology & Society August 2011 31: 303-315, doi:10.1177/0270467611412554, Link: <http://bst.sagepub.com/content/31/4/303.abstract>

...quote: "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. (...) 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."

35. Dr Christopher Hanning. BSc, MB, BS, MRCS, LRCP, FRCA, MD. WIND TURBINE NOISE, SLEEP AND HEALTH, On behalf of the Northumberland & Newcastle Society, July 2012, peer reviewed paper. Link: <http://tinyurl.com/cf4a83h>

...quote: "...Turbines which (...) are sited closer than 1.5km from housing therefore present an unacceptable risk of causing sleep disturbance and high levels of sleep disturbance and wind turbine noise annoyance to those residents ..."

36. Todd NP, Rosengren SM, Colebatch JG. **Tuning and sensitivity of the human vestibular system to low-frequency vibration.** Faculty of Life Science, University of Manchester, UK [Neurosci Lett.](#) 2008 Oct 17;444(1):36-41. Epub 2008 Aug 8.

...quote from the abstract: "Mechanoreceptive hair-cells of the vertebrate inner ear have a remarkable sensitivity to displacement, whether excited by sound, whole-body acceleration or substrate-borne vibration"

...simply the best medical explanation so far why people exposed to LFN (and even ILFN) over a longer period of time consistently show symptoms of what would best be described as "sound-induced kinetosis"...

37. Yukio Inukai, Hideto Taya, Shinji Yamada. **Thresholds and Acceptability of Low Frequency Pure Tones by Sufferers,** *Journal of Low Frequency Noise, Vibration and Active Control*, Vol. 24, No. 3. (September 2005), pp. 163-169, [doi:10.1260/026309205775374433](https://doi.org/10.1260/026309205775374433)

... the data shows clearly that „LFN-sufferers“ do NOT have „better hearing“ (=lower sensory thresholds) than the average person, rather that due to constant exposure to an external low-level LFN source, a significant lowering of the “acceptable” sound pressure level has taken place...It is interesting to note that the noise sources listed have one thing in common (ventilation, A/C, transformer etc.): their spectra will typically show tonal components...

38. Radneva, R. 1997. **Studying the effect of acoustic conditions in the living environment of multifamily buildings on inhabitants (Bulg.).** Khig. Zdraveopazvane 40 (3-4):40-44. EMBASE record 1998252323.

"Studies of 1063 residents in multifamily buildings in Sofia, Bulgaria, experiencing noise level above 60 dBA and infrasound levels from 55 to 78 dB found a statistically significantly increased percentage of persons with psychosomatic complaints (e.g., weakness and fatigue) and sleep disturbance (e.g., restlessness during sleep) versus those exposed to lower level noise and infrasound."

39. Waye KP. **Effects of low frequency noise on sleep.** *Noise Health* 2004;6:87-91, Available from: <http://www.noiseandhealth.org/text.asp?2004/6/23/87/31661>.

...it is interesting to note that the lab studies mentioned gave more or less inconclusive outcomes, whilst the case studies and epidemiological studies all showed patterns of disrupted sleep – a clear indication that the DURATION of the exposure (several weeks / months) is a very relevant, if not a key factor... also, what Prof. Dr. Genuit stated – most of the lab data we have today is based on figures obtained through experiments with high-level, short-term exposure. This is NOT what the IS from wind turbines is like.

40. Castelo Branco N, Alves-Pereira M. **Vibroacoustic disease.** *Noise & Health* 2004 [cited 2012 Sep 26];6:3-20. Available from: <http://www.noiseandhealth.org/text.asp?2004/6/23/3/31667>

... recently confirmed (again) by Chao et al., VAD IS a fact. And a scary one at that. It was once assumed that VAD affected only residents living in very close proximity to LFN sources, but there is evidence from cases in Germany that effects taper out over distance (dose-response-relationship)...

41. da Fonseca J, dos Santos JM, Branco NC, Alves-Pereira M, Grande N, Oliveira P, Martins AP. **Noise-induced gastric lesions: a light and scanning electron microscopy study of the alterations of the rat gastric mucosa induced by low frequency noise.** [Cent Eur J Public Health.](#) 2006 Mar;14(1):35-8. Link: www.szu.cz/svi/cejph/archiv/2006-1-09-full.pdf

... quote: "Superficial erosions were present in the noise-exposed animals. Massive cell death of the gastric epithelium was observed, both by light and electron microscopy." ...