

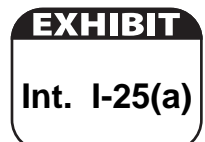
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In-Home Wind Turbine Noise Is
Conducive to Vibroacoustic Disease

Mariana Alves-Pereira
ERISA-Lusofona University, Lisbon, Portugal
m.alvespereira@gmail.com
Nuno A. A. Castelo Branco
Center for Human Performance, Alverca, Portugal
vibroacoustic.disease@gmail.com

Abstract

Introduction. This team has systematically studied the effects of infrasound and low frequency noise (ILFN, <500 Hz) in human and animal models since 1980. Recently, yet another source of ILFN has appeared: wind turbines (WT). Like many other ILFN-generating devices, WT can greatly benefit humankind if, *and only if*, responsible measures are taken for their implementation. Vibroacoustic disease (VAD) is the pathology that is acquired with repeated exposures to ILFN environments (occupational, residential or recreational). This has been demonstrated in numerous scientific articles published in peer-reviewed academic journals over the past 27 years. **Goal.** To evaluate if ILFN levels obtained in a home near WT are conducive to VAD. **Methods.** Case 1: documented in 2004, in-home ILFN levels generated by a port grain terminal (GT), 2 adults and a 10-year-old child diagnosed with VAD. Case 2: isolated farm in agricultural area, four 2MW WT that began operation in Nov 2006, located between 300 m and 700 m from the residential building, 3 adults and 2 children (8 and 12-years-old). ILFN levels of Case 2 were compared to those in Case 1. In both, ILFN was assessed in 1/3 octave bands, without A-weighting, (i.e. in dB Linear). In Case 1, the lower limiting frequency was 6.3 Hz, while in Case 2, it was 1 Hz. **Results.** ILFN levels within the 6.3-31.5 Hz range in the home of Case 2 were higher than those obtained in the home of Case 1. Above, 31.5 Hz, levels varied but were comparable. **Discussion.** ILFN levels contaminating the home of Case 2 are sufficient to cause VAD. This family has already received standard diagnostic tests to monitor clinical evolution of VAD. Safe distances between WT and residences have not yet been scientifically established, despite statements by other authors claiming to possess this knowledge. Acceptance, as fact, of statements or assertions not supported by valid scientific data, defeats all principles on which true scientific endeavor is founded. Widespread statements claiming no harm is caused by in-home ILFN produced by WT rotating blades are fallacies that cannot, in good conscience, continue to be perpetuated. In-home ILFN generated by WT blades can lead to severe health problems, specifically, VAD. Real and efficient zoning for WT must be *scientifically* determined, and quickly adopted, in order to competently and responsibly protect Public Health.



Initial Disclaimer

The authors and the research team they represent would like to clarify that:

- a) No member of this team is party to anti-technology sentiments;
- b) Large industrial plants, such as grain terminals, as well as alternative forms of renewable energy, such as wind turbines, are considered welcome additions to modern technological society by all members of this team;
- c) The data reported herein have been scrutinized under one, and only one, agenda - that of pure scientific inquiry;
- d) In no way can or should this report be construed as a document arguing against the implementation of wind turbines and/or grain terminals;
- e) No member of this research team is employed by the firm that conducted the acoustical measurements reported in this article, nor are there any commercial, financial or professional agreements (contractual or otherwise) between the aforementioned accredited firm and any member of this team;
- f) The consulting activities provided by these authors to Family R are of a purely academic and scientific nature and hence are pro bono.

Introduction

In March of 2007, this team was contacted by an attorney-at-law representing the R. Family, in a case involving the placement of 4, 2 MW wind turbines (WT) near family R.'s property. Located between 321.8m and 642.0m from the residential building (Figs. 1, 2), the 4 WT became operational in November 2006. Two days later the R. family contacted a lawyer to begin court proceedings in order to have the WT removed.



Figure 1. Aerial view of the WT home of Family R., isolated on upper left (dashed square) with the four wind turbines nearby (ovals).



Figure 2. WT home with the two of the turbines (arrows) at approximately 322m and 642m from the home.

In order for acoustical assessments to be accepted as legal documents, they must be performed by an accredited firm. In February 2007, the R. Family hired such a firm – dBLab (1) - to conduct continuous, 12-day, acoustical, wind speed, and vibration measurements. Although Portuguese noise legislation (D.L. 9/2007, January 17th) does not require acoustical evaluations of frequencies below 50Hz, nor dB Linear (dBL) measurements (without the A-weighting network), the accredited firm was additionally asked to obtain data for the entire frequency spectra, down to the lowest limiting frequency of the equipment in use, in 1/3 octave bands and in dBL. Data

were made available to this team, within legal terms and with written consent on behalf of Family R., as well as the accredited firm.

This report documents the levels of infrasound and low frequency noise (ILFN, 6.3Hz-500Hz) encountered in this particular home, due to the operation of 4, 2-Megwatt WT.

Methods

dBLab used two appropriately calibrated and certified 01dB Symphonie sound level meters, equipped with ½" microphone (GRAS, model 23606). Measurements were obtained in periods of 30-min, continuously for 12 days, between Apr 5th-16th, 2007. The lower limiting frequency was 1 Hz. Simultaneous and synchronized accelerometer and wind speed data were also acquired. Measurements were taken within the Master bedroom of Family R., in accordance with the procedures stipulated by Portuguese (NP 1730, Pt 1&2, 1996 and DL 9/2007, January 17th) and International Law (ISO1996, 2003). Measurements conducted outside of the residential building and accelerometer data have not yet been fully analyzed and will not be considered in this report.

Results

Noise Analysis As Per Current Legislation

In accordance with the noise study conducted by dBLab, legally stipulated annoyance levels were exceeded during day (7am-8pm), evening (8-11pm) and night (11pm-7am) hours. dBA noise levels were also exceeded for a sensitive zone during night hours, but were within legal limits for a mixed zone. The local Municipal Authorities where the Family R.'s property is located have not yet classified the area as sensitive or mixed.

Wind Speed varied between 0 and 12.6 Km/h. According to the Portuguese Institute of Meteorology (Table 1), the average wind speed during the month of April 2007 was well below the average values of the previous years.

| | 2004 | 2005 | 2006 | 2007 |
|-----|------|------|------|------|
| Jan | 6,6 | 5 | 6,4 | 4,6 |
| Feb | 7,4 | 8,8 | 8,6 | 6,8 |
| Mar | 11,3 | 12,3 | 10,4 | 11 |
| Apr | 11,4 | 11,5 | 10,7 | 8,9 |
| May | 11,5 | 13,1 | 10 | 10,7 |
| Jun | 12,6 | 11,9 | 11,7 | 12,8 |
| Jul | 13,1 | 14,3 | 12,2 | |
| Aug | 13,4 | 11,6 | 12,3 | |
| Sep | 9,1 | 10,9 | 10,9 | |
| Oct | 9,2 | 10 | 10,9 | |
| Nov | 5,6 | 6,7 | 6,1 | |
| Dec | 6,5 | 7,8 | 5,3 | |

Table 1. Monthly average wind speeds (in Km/h), from 2004 onwards, obtained at the relevant meteorological station near the property of family R, as provided and certified by the Portuguese Institute of Meteorology, on July 27th, 2007.

Acoustical Analysis of Infrasound and Low Frequency Noise

As per the request of this team, spectral analysis of 1/3 octave bands ranging from 1-500 Hz, in dBL were also obtained. Figure 3 compares the residual (no WT blade movement) and environmental (with rotating WT blades) measurements taken within the Master bedroom.

Wind Turbine Home With Same Wind Speed (5.4 Km/h)

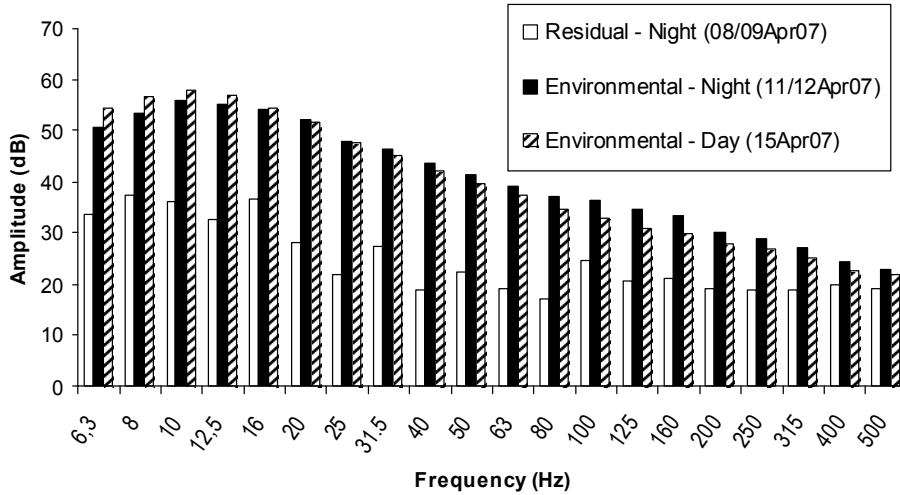


Figure 3. Comparison of 1/3 octave ILFN levels, in dBL, of the *Residual* (no WT blade movement) measurement and the *Environmental* (with rotating WT blades) measurement in the WT home Master Bedroom, with the same recorded wind speed.

Since ILFN is not yet recognized as an agent of disease, it is not covered by legislation. Therefore, permissible exposure levels for ILFN have not yet been determined, and dose-response relationships are unknown. Hence, no adequate standard exists to appropriately compare the ILFN levels in Figure 3 within the context of human health effects.

Analysis Within the Context of Vibroacoustic Disease

Although no generally accepted standard exists for linking the ILFN levels shown in Figure 3 to human health effects, the authors propose that a standard can be established by comparing WT-produced ILFN levels to ILFN levels that have been shown to be conducive to vibroacoustic disease (VAD).

Since 1980, this team has been systematically studying the effects of ILFN on human and animal models. As a result, an illness termed VAD (2-4) has been identified and can be readily diagnosed through echocardiography (5-8) and bronchoscopy (9-13) examinations.

On March 8th, 2007, the first time, the Portuguese Ministry of Labour, through its National Center for Occupational Diseases, granted 100% professional disability to a 40-year-old flight attendant, for having developed VAD during her professional activity. She was diagnosed with VAD in 2001, at the age of 34.

Within the context of VAD studies, the compilation of data on ILFN-rich environments has been ongoing since 2003. Hence, this team is uniquely positioned to provide pertinent data with which to compare the ILFN levels obtained in the bedroom of Mr. and Mrs. R.

Although VAD has been mostly studied within occupational settings (3), in 2004 this team documented (14) its first Portuguese case of environmental VAD in Family F. Residential ILFN was produced by a port Grain Terminal (GT) within line of sight of the home (Figs. 4, 5). From 1982 until 2003, this GT was allowed to operate at any time of the day or night. Operating hours were only restricted in 2003 when new legislation mandated that noisy industrial activities must cease at 11 p.m.

Acoustical measurements at the Family F. home were conducted with a Bruel & Kjaer 2260 sound level meter, equipped with a 1/2" microphone (B&K, model 4189). Measurements were obtained in periods of 15-min, for 3 hours, starting at 9 p.m. (evening period) on Feb 4th, 2004. The lower limiting frequency was 6.3 Hz (14).



Figure 4. Trafaria Deep Water Grain Terminal (TDWGT).



Figure 5. View from the GT home of Family F., located in Lisbon. Across the Tagus River is the TDWGT.

Figure 6 compares the ILFN levels obtained in the WT home of Family R., with those obtained in the GT home of Family F. Below 31.5 Hz, all 1/3 octave bands have higher dB Linear readings in the WT home than in the GT home. The two peaks detected within the GT home, at 40Hz and 50Hz, are specifically related to unidentified GT operations. Above 200 Hz, the GT has higher dB levels than the WT home. The remaining 1/3 octave bands showed similar levels in both homes.

Manifestation of Vibroacoustic Disease in Family F. – GT Home

“Mr. F. is apparently asymptomatic. He complains of a lack of concentration and overall irritation, and has severe bouts of rosacea. He has always lived in the suburbs of the city of Lisbon, and has been working in the centre of Lisbon for the past 10 years. Mrs. F. has been diagnosed with hepatitis A, mononucleosis and allergic rhinitis. While still a student in university, she was once diagnosed with a late-onset epileptic seizure, for which she is currently unmedicated. She complains of body aches, particularly in the right shoulder, left knee, back and neck. X-rays have not revealed any abnormalities. She has always had headaches, mostly radiating along the back of the neck. Approximately 4 or 5 years ago, while in a shopping mall supermarket, Mrs. F. suffered a violent tachycardia, with feelings of faintness. She

was taken to the hospital where a subsequent EKG did not disclose abnormalities. Mrs. F. has worked in governmental administrative offices, in the centre of Lisbon, for the past 16 years. Ten-year-old P. suffered from asthma until the age of 1 year. At 5–8 months of age, he was medicated for reflux, and then again until he was 1 year old. At 8 months he suffered pneumonia. After the age of 1, he began to develop repeated ear infections that were not responsive to antibiotics. At age 3 he underwent ear surgery. At the age of 5, at school, he suddenly lost his vision and was taken to the hospital, where the EEG revealed an epileptic seizure. Nose bleeds without an apparent cause used to be frequent, but have subsided with age. There is no history of rheumatic fever, radiation or asbestos exposure” (14).

Through echocardiography, all three members of this family showed characteristic thickening of cardiovascular structures normally seen in VAD patients (14), namely the pericardium and mitral valve (2, 3, 5-8). The most severe cardiovascular condition was observed in 10-year-old P., most probably because the mother spent the pregnancy gestation months in that same ILFN-rich home. For a more detailed description of this case, see (14).

Late-onset epilepsy, nose bleeds, tachycardia, muscular and joint pain with no imaging corroboration despite sustained patient complaints, are common in VAD patients (2, 3). Respiratory pathology has already been closely linked to ILFN exposure, both by this team (2-4, 9-13, for example) and by other authors (15-17, for example). This family continues to be followed by this team, and has chosen to remain in the ILFN-rich home, but they have relocated their bedrooms to the back of the house.

Grain Terminal Home vs. Wind Turbine Home

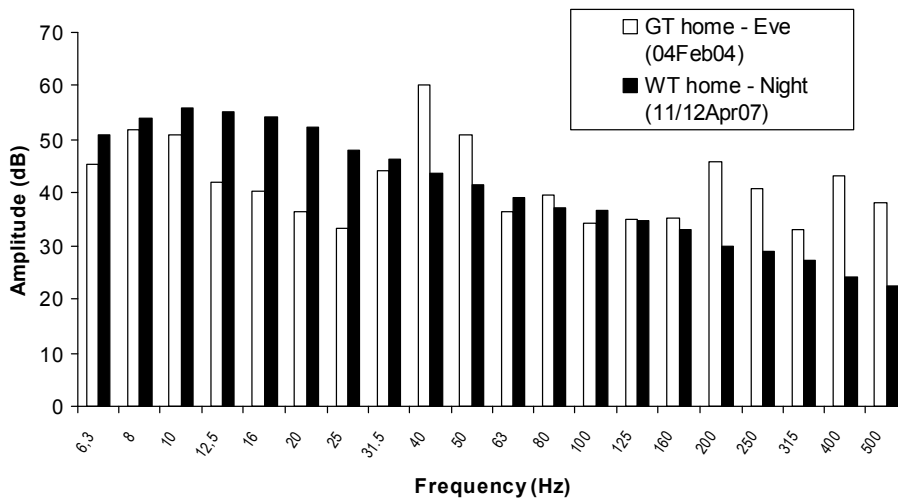


Figure 6. Comparison of the frequency spectra obtained in the GT home of Family F., in 2004, with those obtained in the WT home of Family R., in 2007. The 40Hz peak in the GT home is specifically associated with GT operations. Within the range of 6.3Hz to 31.5Hz, 1/3 octave bands disclose higher dBL levels in the WT home than in the GT home.

Manifestation of Vibroacoustic Disease in Family R. – WT Home

Mr. R has deep concerns about his memory loss, increased irritability and progressive intolerance toward audible noise, all of which he complained about at the very first meeting with this team, in March 2007. Both Mr. and Mrs. R. have developed great difficulty in sleeping continuously throughout the night, as well as non-specific body pain. Upon visiting a general physician at the local State Health Center, Mr. R was prescribed 2 analgesics (anti-inflammatory and spasmolytic) and 2 tranquilizers (diazepam-based and short-term sleep-inducer).

Echocardiograms (routine, non-invasive VAD diagnostic test) of Mr. and Mrs. R. disclosed slight to moderate pericardial thickening (between 1.7mm and 2.0mm, normal for the equipment in use: <1.2mm). Respiratory drive was below normalized values in both adults (46%-53%, normal: >60%), suggesting the existence of brain lesions in the areas responsible for the neurological control of breathing (3).

In mid-March, Mr. and Mrs. R received a letter from their 12-year-old son's school, expressing concern for the growing difficulties of an otherwise outstanding student, *"particularly in English, Humanities and Physical Education. He progressed in Mathematics, which is a field that naturally attracts his type of intelligence. However, in the above mentioned coursework, it seems that [the child] has lost interest, makes a lesser effort, as if he were permanently tired. In Physical Education, an abnormal amount of tiredness is also observed. Is [the child] leading a healthy life? Does he sleep sufficient hours during the night?"*

Given the above school information, and since cognitive and memory disturbances are common and well documented in VAD patients (2, 3), the child received neurophysiological evaluation. Brainstem auditory evoked potentials disclosed asymmetries in the right and left nerve conduction times, and the right I-V interlatency value was at the threshold of normal values (4.44ms). The endogenous evoked potential P300 recording occurred at 352ms (normal: 300ms). This measure reflects the time it takes to recognize and memorize infrequent stimuli. *"Although this result is in accordance with the child's school report indicating that cognitive processes are affected, it is not possible to state that this situation is irreversible. Moreover, in children, P300 recordings often disclose variations that are difficult to interpret. Nevertheless, initial clinical signs of Stage-I VAD are characterized by this type of cognitive impairment and, as such, may be reversible at this clinical stage provided ILFN exposure is suspended"* (18).

The R. Family income is provided by breeding bulls and raising and training horses for bullfights. Horses have exhibited an abnormal behaviour, lying down and sleeping during the day. Tissue fragments have been removed from the farm animals that have been scheduled for slaughter, and will be submitted to the light and electron microscopy analyses that this team usually conducts on ILFN-exposed tissue fragments (3,4). These procedures will be repeated every 6 months, and follow-up reports will ensue. Mr. R. has resident employees who are also receiving all medical tests.

DISCUSSION

ILFN Levels

ILFN levels within the 1/3 octave bands ranging from 6.3Hz to 31.Hz are larger in the WT home than in the GT home. Other bands have a similar dBL level with the exception of the 40Hz and 50Hz bands, and those equal or above 200 Hz. Previous studies strongly suggest that infrasound (≤ 20 Hz) exposure is specifically associated with pericardial thickening (3, 7, 19). Since the family living in the GT home has developed VAD due to in-home ILFN exposure, it is reasonable to assume that the WT family will also progressively develop VAD.

In a perfect world, designed for the most efficient and accurate scientific studies, all noise assessments ought to be conducted with the same equipment and with the same procedures. This is not feasible. So, despite on-site and factory calibrations, a legitimate question will always remain: can the differences between the ILFN levels in the homes of Family F. and Family R. be due to differences in the noise measuring equipment and procedures alone? Despite this legitimate question, these data are sufficient to warrant precautionary measures.

If and when moderate and severe VAD-related symptoms are documented in Family R., this question can be put to rest. This course of action, however, lacks any ethical basis, and could potentially result in a lawsuit, due to negligence.

Occupational vs. Residential Exposures

Occupational exposures to ILFN occur at larger dBL levels (See Fig. 7). However, residential exposure occurs over longer periods of time, affecting all family members (particularly children), and is present during sleep time. In this team's experience, residential ILFN exposures lead to accelerated progression of VAD (9).

Drama or Challenge

Neither the authors nor the team they represent are oblivious to the implications that this study brings to light. However, dramatization of a problem rarely leads to any sort of solution.

Instead of attempting to appease those who are vehement about the notion that WT are inconsequential to human health, and to avoid the useless acrimonious debate that usually ensues after these type data is presented, a challenge is offered up: *zoning laws*. And this immediately leads to the issue of safe distances from the aerodynamic pressure waves produced by rotating WT blades.

Safe Distances...

Scientists have not yet established safe distances between residential buildings and WT. Many scientists have not yet recognized that ILFN is an agent of disease. Hence, the fact that rotating WT blades (analogous to aircraft propellers, or rather, helicopter rotor blades) produce acoustic pressure waves consistent with ILFN phenomena is, to many, simply irrelevant – because ILFN is (erroneously) assumed to be harmless.

...And the Scientific Method

Following a logical rationale: If ILFN is not suspected as an agent of disease, then it does not need to be assessed or investigated as to potential health hazards. Most scientists and physicians do not, therefore, possess information regarding any aspect of ILFN. It follows that until scientific data exist on the subject, no credible claims can be made regarding safe distances between rotating WT blades and residential homes.

Some team could develop an equation that would determine, on a case-specific basis, the safe distance between a home and WT, since the amount of ILFN will depend simultaneously on several factors, including: distance to the building, blade size, wind speed and direction, geology, type of terrain, building resonance properties of both ILFN and solid-to-solid ground vibration transmission, type of vegetation as well as its quantity and distribution.

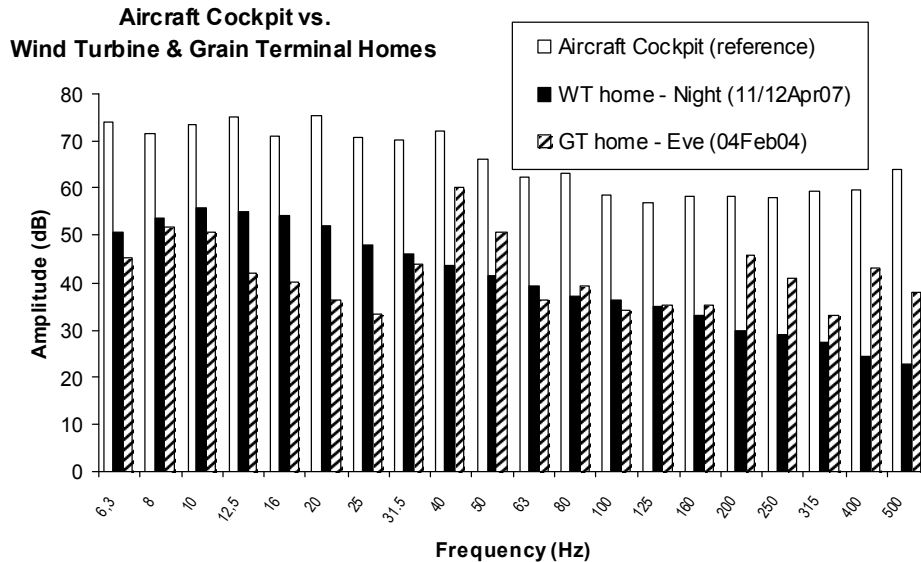


Figure 7. Comparison of 1/3 octave ILFN levels, in dBL, of the WT home, the GT home, and the reference ILFN levels used for occupational exposures by this team (Aircraft Cockpit (19)).

Prospects of New Data

As certified by the Portuguese Institute of Meteorology (Table 1), the average monthly wind speeds in August are generally higher than in April. Hence, dBLab will repeat all measurements during the month of August. WT-generated ILFN is strongly related to the acoustic pressure waves aerodynamically generated by rotating blades. This is somewhat analogous to the infrasound (≤ 20 Hz) levels in airplane cockpits, which are larger with increasing aircraft speed, due to the impact of the aerodynamic airflow on the nose of the aircraft (19).

The neurophysiology evaluation of the child will be repeated in late September, after he has spent 2 months away from the ILFN-contaminated home, and in December, non-invasive VAD diagnostic tests will be repeated on all family members and

resident employees. Electron microscopy studies of animal tissue fragments are ongoing.

CONCLUSIONS

ILFN levels within the range of 6.3Hz to 31.5Hz obtained at the WT home are higher than those obtained at the GT home. Family members residing in the GT home have been diagnosed with ILFN-induced pathology, i.e., VAD. With time, it is highly probable that the family residing at the WT home will also develop severe VAD, since they are already exhibiting symptoms consistent with early VAD.

Precautionary measures regarding the placement of WT near inhabited buildings are justified. Safe distances between WT rotating blades and inhabited buildings have not yet been determined by the scientific community.

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