Champaign County Ohio Noise Questions

Presented by:

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Purpose and Scope

The Champaign County Wind Study Group has tentatively concluded that the noise standard +5dB above background is appropriate to mitigate potential noise impacts associated with the siting and operation of wind turbines in Champaign County. The study group requests your opinion regarding the following issues related to the implementation of this standard.

1. Credentials and Experience

What are your credentials and experience concerning monitoring sound levels for industrial wind turbines and community noise?

Education and Business Background

- General Motors Institute
  - Mechanical Engineering Degree, 1971
    - Specializing in Noise Control
- Officer/Director/Owner:
  - E-coustic Solutions (2006-Present)
  - Safe@Work®, Inc. (1999-Present)
  - James, Anderson & Associates, Inc. (JAA) (1983-2006)
  - Total Environmental Systems, Inc. (1972-1983)

Adjunct Instructor/Course Instructor

- Michigan State Univ.
  - Department of Communicative Sciences and Disorders (1990-present)
- Central Mich. Univ. (thru 2001)
  - Department of Audiology
- American Industrial Hygiene Assoc.
  - Various noise measurement and control course for Industrial Hygienists.
  - Chapter on Community Noise (with R. Anderson) for AIHA Noise Handbook. (1994-2001)
- Michigan Department Of Public Health
  - Course on "Health in the Work Place" 1981-1985
- GM University, Continuing Education (1985-2004)
  - Assessing worker sound exposure
  - Noise control for Engineers
  - Hearing Conservation for Safety Engineers

Papers and Presentations

1971-GMI thesis titled: "Sound Power Level Analysis, Procedure and Applications".

1973-"Computer Analysis and Graphic Display of Sound Pressure Level Data For Large Scale Industrial Noise Studies", Proceedings of Noise-Con 1973, Washington D.C..

1973-Published: "Isograms Show Sound Level Distribution In Industrial Noise Studies", Sound & Vibration

1975-Published: "Computer Assisted Acoustical Engineering Techniques", Noise-Expo 1975, Atlanta

1981-Published: "A Practical Method For Cost-Benefit Analysis of Power Press Noise Control Options", Noise-Expo 1981, Chicago, Illinois

1993-Invited paper: "An Organization Structured Sound Exposure Risk Assessment Sampling Strategy" at the 1993 American Industrial Hygiene Conference

1993-Invited paper: "An Organization Structured Sound Exposure Risk Assessment Database" at the Conference on Occupational Exposure Databases, McLean, VA sponsored by ACGIH

Professional Associations

- Member-Institute of Noise Control Engineers, 1972-Present.
  - Made a Full Member (e.g. requires peer review of work and qualifications) 1992-Present
- Voted into American National Standards (ANSI) S12 Working Group
  - S12 has oversight responsibility for all applied ANSI noise control standards including community noise. 1997-2006. Coordinates ANSI with IEC and ISO standards.
- Kettering Institute's Applied Physics Advisory Board (1997-Present)

Community Noise Projects

- All GM Facilities Built Since 1976
- GM/Ford Foundries, Stamping And Forging Operations (Incl. Defiance)
- Goodyear's American, European And Pacific Rim Operations
- ABI's Ohio Sea World And Can Manufacturing Operations
- Pratt And Whitney's Jet Engine Test Facility, Florida
- Outdoor Concert arena's (Illinois and Michigan)

Wind Turbine Experience

- Michigan
  - Huron County, MI
    - Noble Environmental (Bingham Twp.)
    - Deere and Co. (Pigeon) (Operating)
  - Mackinac City, MI (Operating)
- Wisconsin
  - Town of Chilton/Calumet County, WI
  - Fondulac (Start up)
  - Kewaunee (Operating)
  - Trempealeau County
  - Town of Union
  - Elcho (Operating)
- West Virginia
  - Alleghany (Startup)
- Review of other studies and EIS reports

Describing Sound: dBA, dBC, Freq., Level

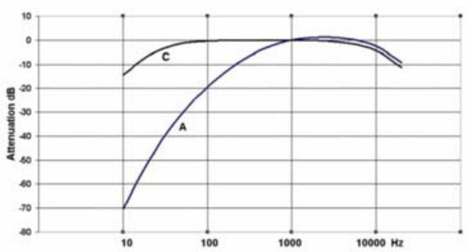


Figure 4. Sound level meter weighting curves – A and C.

2. What are we measuring?

a) Based on your experience with community noise are there any unique noise issues that should be considered regarding wind turbines?

Wind Turbine Sound (audible/not audible)

- Audible
  - Reasonably steady sound of blades moving through air
  - Swishes, Thumps, etc.
- Non-auditory
  - Body sensations
  - Structural response

Elements of Wind Turbine Sound

FIGURE 1-3 Structure of a wind turbine. Source: Alliant Energy 2007. Reprinted with permission; copyright 2007, Alliant Energy.

Wind Turbine Sound

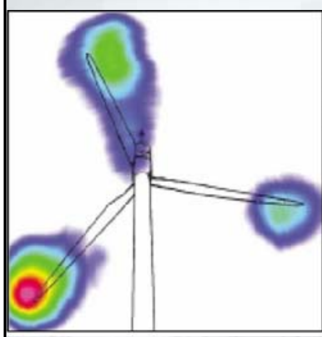


Figure III.1: an 'acoustic photograph' showing the high speed tips of a wind turbine radiate most sound; colors from centre to outside contour indicate an decreasing sound level (photo: Acoustic Camera, GFaI, Berlin)

Low Frequency Sound

Frequency Hz	1	10	25	50	100	150	200
Wavelength m	340	34	13.6	6.8	3.4	2.27	1.7

Table 1. Frequency and wavelengths of low frequency sound.

Van den Berg on Wind Turbine Sound

"…there is a greater mismatch between optimum and actual angle of attack when the blade passes the mast (where there was already a mismatch due to the tower), causing higher blade loading and more turbulence. **This effect is readily audible when night falls: the blades start clapping or beating at the blade passing frequency. The effect is stronger when stability increases**, and also when wind speed at hub height increases up to the point where friction turbulence overrides stability and the atmosphere becomes neutral."

Van den berg on 'beating' sound

"The effect is confirmed by residents near wind turbines who mention the same common observation:

- often late in the afternoon or in the evening the turbine sound changes to a more 'clapping' or 'beating' sound, the rhythm in agreement with the blade-passing frequency. It is clear from the observations that this is associated to [with] a change to a higher atmospheric stability.
- The increased annoyance has not been investigated as such, although there are indications from [the] literature [that] this effect is relevant.
- *It is of increasing relevance as the effect is stronger for modern (that is: tall) wind turbines*."

Wind Turbine Noise vs. Annoyance

SWEDISH ENVIRONMENTAL PROTECTION AGENCY Report 5308
Noise annoyance from wind turbines – a review

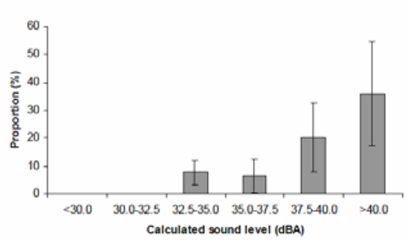


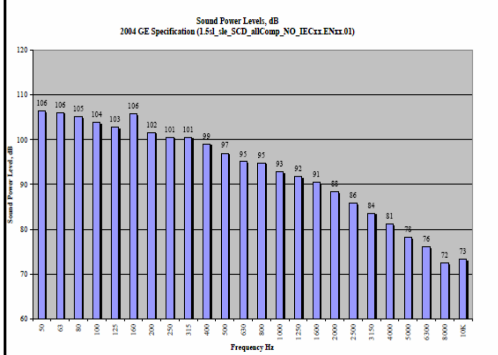
Figure 1. The proportions very annoyed by noise outdoors from wind turbines (95%CI) at different A-weighted sound pressure levels [Pedersen and Persson Waye 2002].

Noise_annoyance_from_WT_Pedersen_Aug03.pdf

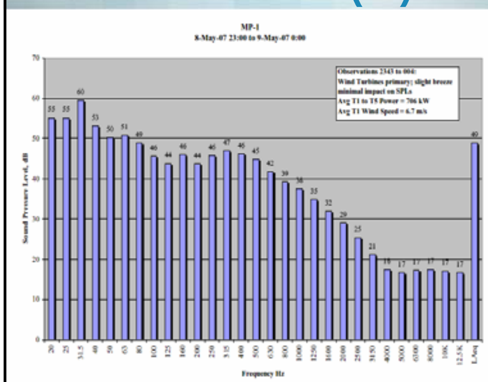
2. What are we measuring?

b) Are low frequency noises emitted from wind turbines?

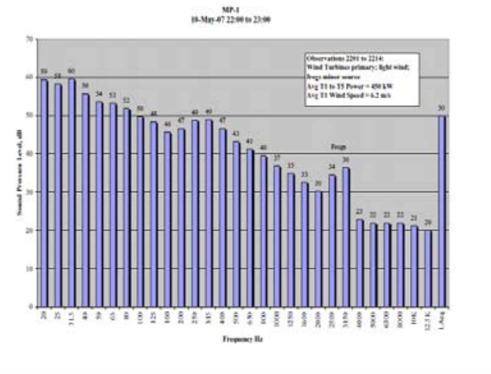
GE Sound Power Level (1.5 Mwatt series)



Sound Pressure Levels (dB)-Mars Hill



Sound Pressure Levels (dB)-Mars Hill



2. What are we measuring?

c) What would I classify as infrasound or low frequency sound?

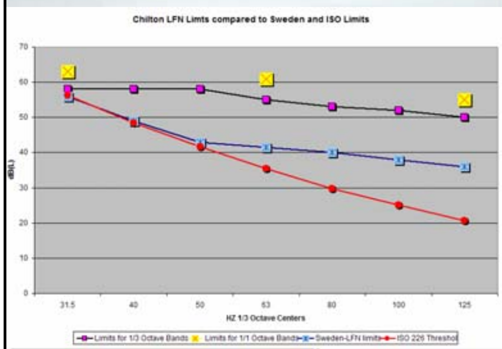
How Infrasound is perceived

A research paper by G Rasmussen looked at body vibration exposure at frequencies of 1-20 Hz. Part of a table shows:-

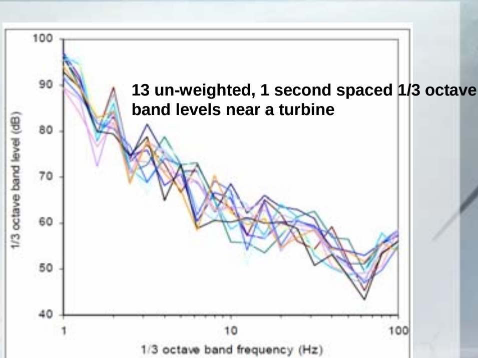
Symptoms	Frequency
General feeling of discomfort	4Hz – 9Hz
Head symptoms	13Hz – 20Hz
Influence on speech	13 Hz – 20 Hz
Lump in throat	12 Hz – 16Hz
Chest pains	5Hz – 7Hz
Abdominal pains	4Hz – 10Hz
Urge to urinate	10Hz – 18Hz
Influence on breathing movements	4Hz – 8Hz

Also in the region 60-90 Hz disturbances are felt which suggest eyeball resonances, and a resonance effect in the lower jaw/skull system has been found between 100-200 Hz

Low Frequency Sound and ISO Thresholds



Van den Berg-Study of Wind Turbine LFN



2. What are we measuring?

d) Do sound levels from different model/size wind turbines vary?

2. What are we measuring?

e) What is the IEC Standard 61400-11 and how does it affect baseline noise testing?

3. How do we measure it?

a. What modeling or measuring testing standard should be followed in order to assess compliance with the +5dB proposed noise standard both in connection with any pre-construction approvals that may be required and during operation of wind turbines?

Modeling

Distance to tower base (ft)	distance to tower base (m)	Distance to hub (m)	0.0000	0.0000	0.0000	0.0001	0.0002	0.0005	0.0013	0.0027	0.0047	0.0099	0.0290	0.0300	—	—	Distance to tower
250	76	118	71.2	68.2	66.2	64.2	62.5	61.3	57.0	53.0	49.1	44.6	37.4	30.3	74.8	55.1	250
500	152	172	67.3	64.3	62.3	60.3	58.6	57.4	53.1	49.1	45.2	40.6	33.6	26.5	70.9	51.3	500
1000	305	315	62.0	59.0	57.0	55.0	53.3	52.1	47.8	43.8	39.9	35.3	28.3	21.2	65.7	46.0	1000
1200	366	374	60.6	57.6	55.6	53.6	51.9	50.7	46.4	42.4	38.4	33.8	26.8	19.7	64.2	44.6	1200
1500	457	464	58.7	55.7	53.7	51.7	50.0	48.8	44.5	40.5	36.6	32.0	25.0	17.9	62.3	42.7	1500
1750	533	539	57.4	54.4	52.4	50.4	48.7	47.5	43.2	39.2	35.3	30.7	23.7	16.6	61.0	41.3	1750
2000	610	615	56.2	53.2	51.2	49.2	47.5	46.3	42.0	38.0	34.1	29.5	22.5	15.4	59.9	40.2	2000
3000	914	918	52.8	49.8	47.8	45.8	44.1	42.9	38.6	34.6	30.7	26.1	19.0	11.9	56.4	36.7	3000
4000	1219	1222	50.3	47.3	45.3	43.3	41.6	40.4	36.1	32.1	28.2	23.6	16.6	9.4	53.8	34.2	4000

Noise Propagation Modelling

Noise propagation modelling is recommended within Section 4 of NZS6808:1998 to be carried out prior to the development of a wind farm in order to assess the potential noise impact. The predictions are recommended to be carried out using equation 1 as follows:

$$L_R = L_W - 10\log(2\pi R^2) - \Delta L_a \qquad \text{Equation 1}$$

Where

L_R = The sound pressure level of noise received (in dBA) at distance R

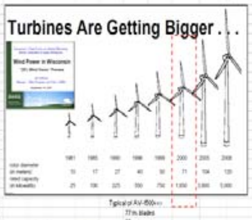
L_W = The sound power level of the noise source(s) (in dBA) as nominated within sound spectrum data provided by the WTG manufacturer (IEC 61400 - Part 11)

R = The distance between the source and the receiver in metres

$\Delta L_a = \alpha_a R$

α_a = Attenuation of sound due to air absorption, in dBA/m for broadband sound which is typically 0.005 dBA (Ref. ANSI S1.26 - 1995)

The prediction method given in NZS6808 is a simple method of determining the sound pressure level at a given position relative to a wind farm. Its simplicity means that it can be implemented quickly, without specialist software, and it is a robust and transparent model. However it does not take into account ground absorption, barrier



REFERENCES-ANSI Standards

- • ANSI S12.9-1988/Part 1 (R 2003) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 1.
- • ANSI S12.9-1992/Part 2 (R 2003) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 2: Measurement of Long-Term, Wide-Area Sound.
- • ANSI S12.9-1993/Part 3 (R 2003) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 3: Short-Term Measurements with an Observer Present.
- • ANSI S12.9-2005/Part 4 American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 4: Noise Assessment and Prediction of Long-Term Community Response.
- • ANSI S12.9-1998/Part 5 (R 2003) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 5: Sound Level Descriptors for Determination of Compatible Land Use.
- • ANSI S12.9-2000/Part 6 (R 2005) American National Standard Quantities and Procedures for Description and Measurement of Environmental Sound, Part 6: Methods for Estimation of Awakenings Associated with Aircraft Noise Events Heard in Homes.
- • ANSI S12.17-1996 (R 2006) American National Standard Impulse Sound Propagation for Environmental Noise Assessment.
- • ANSI S12.18-1994 (R 2004) American National Standard Procedures for Outdoor Measurement of Sound Pressure Level.

3. How do we measure it?

b. Does low frequency noise from wind turbines present unique considerations for noise testing and modeling?

World Health Org. on LFN

The World Health Organization is one of the bodies which recognizes the special place of low frequency noise as an environmental problem. Its publication on Community Noise (Berglund et al., 2000) makes a number of references to low frequency noise, some of which are as follows:

- *" It should be noted that low frequency noise, for example, from ventilation systems can disturb rest and sleep even at low sound levels"*
- ***"For noise with a large proportion of low frequency sounds a still lower guideline*** **(than 30dBA)** ***is recommended"***
- *" When prominent low frequency components are present, noise*
- *measures based on A-weighting are inappropriate"*
- *"Since A-weighting underestimates the sound pressure level of noise with low frequency components, a better assessment of health effects would be to use C-weighting"*
- *"It should be noted that a large proportion of low frequency components in a noise may increase considerably the adverse effects on health"*

*"**The evidence on low frequency noise is sufficiently strong to warrant immediate concern"***

DEFRA: dBA underestimates Annoyance

8.2.4 **Annoyance and the dBA.** A comparison of a band of noise peaking at 250Hz with a band peaking at 100Hz, whilst both were adjusted to the same A-weighted level, showed that the annoyance from the low frequency noise was greater than that from the higher frequency noise at the same A-weighted level (Persson et al., 1985). This work was subsequently extended (Persson and Bjorkman, 1988; Persson et al., 1990) using a wider range of noises, for example, peaking at 80Hz, 250Hz. 500Hz and 1000Hz, leading to the following conclusions:

There is a large variability between subjects.

The dBA underestimates annoyance for frequencies below about 200Hz.

For broadband low frequency noise, the underestimate was found to be 3dB for levels around 65dB(Linear) and 6dB for levels around 70dB(Linear). Similar results had been obtained in earlier work (Kjellberg et al., 1984). Two broadband noises were investigated, in which one was dominated by energy in the 15-50Hz range. Twenty subjects compared the two noises within the dynamic range 49-86dBA. At equal A-weighted levels, the noise dominated by the low frequency component was perceived as 4-7dB louder and 5-8dB more annoying.

3. How do we measure it?

c. **How does your recommended testing standard monitor and account for low-frequency noise from wind turbines and what is the difference between an A weighted noise test and a C weighted test?**

Assessing WES sounds

- **Background pre-construction sounds in community**
- **Limits for audible sounds (dBA)**
- **Limits for non-audible sounds (LFN and Infra sound (frequency specific)**
- **Post-construction Compliance**
- **Complaint Resolution**

Recommendations for Sound Requirements

- Audible Sound Limit
  - Not-to-exceed the background L90+5 dB when measured during a pre-construction noise study for the quietest time of evening or night. Noise sensitive sites are to be selected based on wind farm's predicted sound emissions (dBA and 1/3 octave to blade passage frequency) which are to be provided by developer.
  - 5 dB penalty for pure tones or when the sound emissions fluctuate in amplitude or frequency over time in reasonable sync with the blade revolution.
- In-Audible (e.g. Low Frequency) Sound Limit
  - Not to exceed dBC-dBA greater than 20 dB inside or outside any occupied structure and not-to-exceed 65 dB in any 1/3 octave band at frequencies of 25 Hz and lower to the blade passage frequency of the WE

Recommendations for Sound Requirements

- General Clause
  - Not to exceed 40 dBA within 100 feet of any occupied structure (or for more safety beyond the property line of the host's property.)
- Requirements:
  - All instruments must meet ANSI Type 1 performance specs.
  - Procedures must meet ANSI S12.9 and other applicable ANSI standards.
  - Measurements must be made when ground level winds are 10 mph or less. Background sound measurements are with winds of 5 mph or less. Wind shear in the evening and night often result in low ground level wind speed. At turbine fan heights, the wind is at or above nominal operating wind speeds.

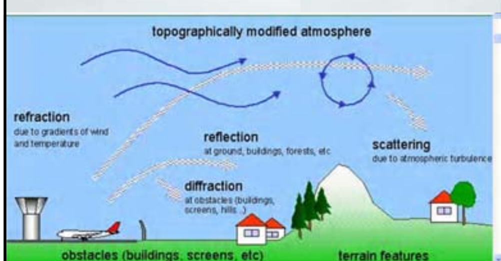
Recommendations for Sound Requirements

- Pre-Build background sound study and Post-Construction working for the local community.
- Funding of the studies may be through fees or directly assessed to wind developer Study should be done be a qualified Noise Control Engineer, preferably a Full or Board Certified Member of INCE

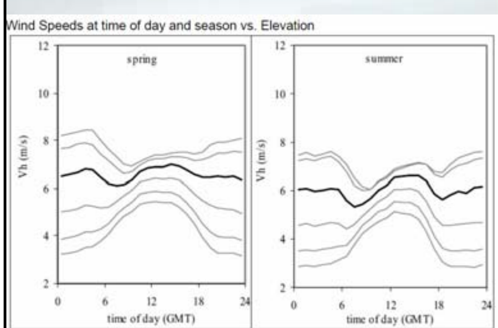
3. How do we measure it?

d. Are topography, and daytime versus nighttime a significant consideration for testing or modeling noise impacts from wind turbines?

Topography



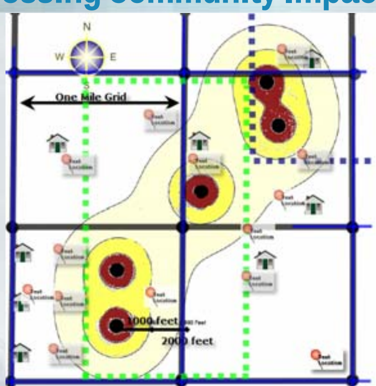
Wind Shear



3. How do we measure it?

e. How large an area should be studied?

Assessing Community Impact



4. What do we measure it with?

a. In your experience how have local governments successfully monitored sound?

Effective Community Sound Regulations

- **Protect the health and safety of the community**
- **Provide the WES applicant with guidance to assist in site selection and WES characteristics to avoid problems after construction**
- **Establish rules for complaint resolution**
- **Specify methods for measuring community background and WES sounds using ANSI standards.**

IEA Recommendations for Background Noise Tests: L_{90} or L_{95}

C.1 Acoustic measurements

Ambient sound levels should be measured using the A-weighted L_{Ax} percentiles over consecutive 10 minutes intervals, L_{A90} and L_{A95} are those more often employed.

The equipment should fulfill the requirements given in chapter 4. The microphone should be mounted on a tripod at 1.2 - 1.5 m above ground level, fitted with a windscreen, and placed in the vicinity of, and external to, the property, and in a free-field position according to clause 5.2.1.

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http://www.ieawind.org/Task_11/RecommendedPract/10_Noise.pdf

British Wind Energy Association: L_{90}+5

The Wind Turbine Noise Working Group, established by the DTI in 1996, developed guidelines[8] for wind farm developers on noise from wind turbines. These have been adopted as part of the best practice standards set by the British Wind Energy Association and are consequently followed by the majority of the UK wind industry. Preliminary recommendations from the Wind Turbine Noise Working Group are that turbine noise levels should be kept to within 5 dB(A) of the average existing evening or night-time background noise level.

4. What do we measure it with?

b. What equipment would you recommend?

ANSI Type 1 Sound Level Meters