PLEASANT RIDGE EXHIBIT
57

Information Brief

Springfield-Sangamon County Regional Planning Commission

Initial Report: 1.6.10
Updated: 3.2.12; 4.5.12

Key Findings:

The SSCRPC finds that while some living near wind farms may find the sound generated by such facilities to be an annoyance – and this annoyance may have certain effects and be related to negative opinions concerning wind energy facilities – there is no current reliable empirical or epidemiological evidence that the sounds generated have adverse health effects. This includes the effects reported as coming from low-frequency and infrasound.

A recent review by an expert panel brought together by the Commonwealth of Massachusetts lends credence to these findings.

While there may be other policy reasons for changing site location and setback requirements, the SSCRPC does not find that this should be necessitated by public health concerns.

The Springfield-Sangamon County Regional Planning Commission

Room 212
200 South 9th Street
Springfield, Illinois 62701

Phone: 217.535.3110
Fax: 217.535.3110
Email: sscrpc@co.sangamon.il.us

www.sscrpc.com

The Effects of Wind Turbine Sound on Health

A Consideration of the Literature

Issues related to sound generated by wind energy turbines have led to some debate regarding the appropriateness of wind energy facility site location and setback requirements, with opponents of wind farms arguing that certain sounds generated by the facilities may cause health problems for those who live nearby necessitating greater setback distances.

Because of the importance of public health and safety to wind energy facility regulation, the Springfield-Sangamon County Regional Planning Commission (SSCRPC) conducted a brief review of the available and noteworthy literature on the subject of wind turbine sound. Particular attention was given to low-frequency and infrasound generated by wind turbines as this sound is often the focus of those arguing for additional regulation and greater setback distances. As is the practice of the SSCRPC in conducting such reviews, preference was given to published scholarly studies that were subject to peer review or that provide sufficient methodological information to allow for peer review.

Consistent with other reviews of the literature, the SSCRPC found that while some living near wind farms may find the sound generated by such facilities to be an annoyance, there is no reliable empirical evidence at this time that the sounds generated by wind energy facilities – including low-frequency and infrasound – are a threat to public health. Annoyance may lead to stress and other negative health outcomes for a small percentage of the population, but the research seems to indicate that this annoyance is often generated by non-sound related factors rather than the sound created by the turbines itself, with sound becoming a negative surrogate for these other factors.

The following pages outline the information reviewed.

Wind Energy Facilities and Sound

There is no question that wind turbines generate sound. This sound is generally created in two ways: as mechanical sound, created by the equipment internal to the turbine, or as aerodynamic sound, created by air moving past the rotor blades (Rogers et al., 2006, pp. 10-13; Colby et al., 2009, pp. 3-1 – 3-12). To understand the implications of sound generated by wind energy facilities, it is important to understand a bit about how sound is measured and the types of sound created by wind turbines[1].

Sound is most often considered in two ways: the sound's magnitude, volume or *pressure* (the sound's intensity*)*, which is measured in decibels (dB), and the sound's pitch, tone or *frequency* (the sound's oscillations per second), which is measured in hertz (Hz). Since both sound pressure and frequency have an effect on the perception of a sound, they are often brought together in a scaled set of measures (see Colby et al., 2009, pp. 3-2 – 3-3, and C-1). For example, a pneumatic drill at 50 ft. distance is said to have an "A-Weighted Sound Level" of 80 dB, and is considered "annoying", while light auto traffic is measured at 50 dB under the same system, and is considered "quiet". It is important to understand the difference between sound pressure and frequency, as people tend to notice sound from wind turbines almost linearly as sound pressure increases (Pederson and Waye, 2004, 2007, 2008; Knopper and Ollson, 2011, p. 3), and because sound pressure is relevant to the issue of low frequency or infrasound, which will be discussed further below.

The Wind and Hydropower Technologies Program of the U.S. Department of Energy (2009) notes four types of sound associated with wind turbines that can differ in both sound pressure and sound frequency:

- **Broadband Sound:** Made up of a combination of sound waves with different frequencies. Broadband sound has no distinct pitch and can be described as a humming, whooshing, or swishing sound. Broadband sound does not start or end abruptly. It has frequencies higher than 100 Hz and is typically caused by the interaction of the turbine blades with atmospheric turbulence. Low-frequency sound (20 Hz to 100 Hz) usually occurs only when the turbine blades are located on the downwind side of the turbine tower. The blades experience airflow deficiencies because the airflow is partially blocked by the tower. Low-frequency sound can often be felt before it is clearly heard.

- **Infrasonic Sound:** Infrasound exists at frequencies of less than 20 Hz and is always present in the environment. Infrasonic sound can propagate further than higher, more audible frequencies, but it also has higher levels of dissipation and blends in with ambient noise. Though infrasound is barely audible, it can cause structural vibration, such as window rattling.

- **Impulsive Sound:** Is generated when disturbed airflow interacts with turbine blades or when multiple turbines making swishing noises synchronize in stable winds. Impulsive sounds are characterized by thumping sounds that can vary in amplitude over time. As with low-frequency sound, impulsive sound from a single turbine tends to occur in "downwind" turbines as a result

[1] For a useful review of wind turbine sound and how it is measured, see Bastasch et al., 2006.

of air flowing around the tower to reach the blades. The sounds produced by downwind versus upwind turbines will be discussed further below.

- **Tonal Sound:** Can be caused by: the rotation of shafts, generators, and gears operating at natural frequency; unstable airflow over holes or slits; or due to non-aerodynamic instabilities interacting with the blade surface. Tonal sounds can have a distinct pitch, like a musical note, and do not start or end abruptly.

The sound pressure of a modern wind turbine is normally in the range of 35 to 45 dB at a distance of about 1000 feet, which is comparable to the sound level in a typical home (50-60 dB) and less than that found in a typical office environment (60-70 dB). One acoustic consultant compared the sound level of a wind turbine at 50-100 meters (about 165 ft. to 330 ft.) to the sound of a flowing stream (Hayes McKenzie, 2000). The most recent study to look at sound generated by wind turbines (Ellenbogen et al., 2012, p. ES-5), reported that typically, at distances larger than 400 m. (about 1,300 ft.), the sound pressure levels for modern turbines are less than 40 dB(A), which is below the level associated with annoyance in the epidemiological studies an expert panel reviewed.

While the human ear can detect a very wide range of sound levels (magnitude, pressure or loudness) and sound frequencies (pitch or tone), typically the frequencies of sound that can be heard range from about 20 Hz to 20,000 Hz (Rogers et al., 2006, p. 4). As noted above, understanding the difference between sound pressure (measured in decibels) and sound frequency (measured in hertz) is particularly relevant to the debate concerning wind turbines because of the contentions made about low-frequency sound and infrasonic or “infrasound”.

Wind Turbine Sound and Health

While the sound generated by wind turbines may be considered “noise” by some and be a nuisance, more troubling is the contention by wind farm opponents that the sound generated by the turbines, particularly low-frequency sounds and infrasound, may have detrimental effects on human health and therefore necessitate greater separation from human habitation. As sometimes reported, these effects have even been termed “wind turbine syndrome” and “vibroacoustic disease” by their advocates (for example, Nina Pierpoint and Mariana Alves-Pereira, respectively). Because of this concern, the SSCRPC specifically sought information concerning the effect that low frequency and infrasound generated by wind turbines might have on human health.

Low-frequency sound is generally near the bottom of human perception, at frequencies between 10 and 100 Hz. Low-frequency sounds are not uncommon and are usually present in the environment as background noise. What is called infrasound overlaps with low-frequency sound frequencies, and is generally described as existing at frequencies below 20 Hz but can occasionally be perceived at frequencies as low as 2 Hz. Infrasound is “always present in the environment and stems from many sources including ambient air turbulence, ventilation units, waves on the seashore, distant explosions, traffic, aircraft, and other machinery” (Rogers et al., p. 8).

Infrasound and low-frequency sound can be perceived as a mixture of auditory and tactile sensations, with the primary human response to infrasound being “annoyance” (Rogers et al.,

p. 9; see also, Pedersen and Waye, 2007, and van den Berg, 2004). However, while frequency defines low-frequency and infrasound, sounds of these frequencies are not in-and-of themselves problematic in the absence of sufficient sound pressure.

Infrasound can cause humans to experience fatigue, apathy, abdominal symptoms or hypertension when they are exposed to infrasound levels at about 115 dB and above, but this sound pressure is much higher than one finds with utility grade wind turbines. Addressing the effect of low frequency and infrasound produced by wind turbines on humans, Bastasch and his colleagues point out that "*there is no evidence of adverse effects below 90 dB*" (p. 9; italics in the original). This is particularly noteworthy as wind turbines, as reported above, normally exhibit sound pressures in the range of 35 to 45 dB at a distance of about 1000 feet.

The infrasound generated by wind turbines is affected by a number of variables (see Rogers et al., pp. 16-20, and Wagner et al., 1996), but one of some importance – and alluded to in the section above – relates to the design of the turbines. Some early wind turbines had "downwind" rotors that generated significant levels of infrasound. This downwind design is rarely used in modern "utility-scale" wind power turbines (Rogers et al., p.13). Modern "upwind" rotors emit broadband sound emissions, including low-frequency sound and some infrasound, but the "swishing" sound of the turbine often suggested as a product of low-frequency or infrasound is merely the "amplitude modulation at blade passing frequencies of higher frequency blade tip turbulence" and does not contain low frequencies. (Rogers et al., p. 13).

Bastasch and his colleagues report on the difference between the older "downwind" and newer "upwind" turbines in this regard as well:

> Concern about infrasound from wind turbines may have originated from the experience of neighbors of early wind turbine designs with downwind rotors (rotors downwind of the tower). The effect of the sudden decrease in wind speed behind the tower on the flow around the blades created objectionable levels of infrasound. In contrast, all modern utility scale wind turbine (sic) have upwind rotors that produce significantly lower infrasound emissions. When standing close to a modern wind turbine one may hear a swish-swish sound at the blade passing frequency. This is an amplitude modulation of higher frequency blade tip turbulence and does not contain low frequencies. (2006, p. 10)

Whatever the genesis of the concern, the effect of low-frequency and infrasound on human health is an issue that has been debated by both wind farm opponents and proponents. While there is a very large literature dealing with the effects of sound on the human body, and it is often discussed in the occupational health literature, the SSCRPC found less peer-reviewed scholarly work specific to wind turbines; particularly as it relates to detrimental effects. This may largely be due to there being general concurrence that, and as various studies of low-frequency and infrasound indicate, the sound generated by wind turbines does not present a hazard.

Rogers (2005), for example, reviewed sound profiles measured at 80 m. to 118 m. (about 263 to 387 ft.) from various turbines that showed a range of sound pressure levels at various frequencies, including infrasonic. He found that the maximum infrasound pressures were well below the problematic 90 dB noted above (see also, Bastasch et al., p. 10). Leventhal (2004) found similar results from measurements taken at 100 m. (328 ft.) from a single turbine to calculate low frequency sound pressure levels at a distance of 400 m. (1312 ft.) from a wind farm with 19 turbines.

One of the most cited reports that considered the relevance of wind turbine sound to human health is that by Leventhall (2006a), who found no reliable evidence that infrasound levels below the hearing threshold had an adverse effect on the human body (p. 30) and reported that they were of "no consequence" (p. 34). This was also noted by Rogers and colleagues (p. 10) in regard to both "physiological or psychological effects".

Leventhall writes:

> It has been shown…that there is insignificant infrasound from wind turbines and that there is normally little low frequency noise. Turbulent air inflow conditions cause enhanced levels of low frequency noise, which may be disturbing, but the overriding noise from wind turbines is the fluctuating audible swish, mistakenly referred to as "infrasound" or "low frequency noise". Objectors' uninformed and mistaken use of these terms …, which have acquired a number of anxiety-producing connotations, has led to unnecessary fears and to unnecessary costs, such as for re-measuring what was already known, in order to assuage complaints. (2006a, p. 35).

To assess the possibility that wind turbines may create unacceptable levels of low frequency and infrasound, O'Neal et al. (2011), conducted a study to measure wind turbine noise outside and inside residences near the Horse Hollow wind farm in Taylor and Nolan counties, Texas. Data was collected over a week both indoors and outdoors under a variety of operational conditions (though it should be noted that wind speeds were low during the study period) and at two distances from the nearest wind turbines: 1000 ft. and 1500 ft. The researchers found that at both distances the measured low frequency and infrasound were less than the standards and criteria set by a number of national and international agencies, and "concluded that results of their study suggest that there should be no adverse public health effects from infrasound or low frequency sound" at the distances studied (Knopper and Ollson, p. 6).

There is additional support for Rogers', Leventhall's and O'Neal's findings.

Consider first that if low-frequency sound emitted by wind turbines is harmful to health, city dwelling would be impossible due to the similar levels of ambient low-frequency sound normally present in urban environments (Colby, et al., p. 4-1). This is but one of the reasons why acoustic experts find that low-frequency sound from wind turbines is of no consequence to health (see, for example, Jakobsen, 2004, and Bastasch et al., 2006).

But even if the research were to indicate a relationship, the effect would most likely be insignificant because, as Leventhall notes, only low levels of infrasound and low-frequency sound have been found by other studies of wind turbines (Jakobsen, 2004; van den Berg, 2004). As a general rule, higher frequency sounds present a greater risk of adverse effect than do lower frequency ones (Colby et al., pp. 3-12 – 3-14).

The most complete review of the literature concerning the effect of wind turbine sound on health was provided by an eight-member expert panel brought together by the American Wind Energy Association and the Canadian Wind Energy Association (Colby et al., 2009). This review, published in December 2009, assessed the contentions of those suggesting that wind turbines have a detrimental affect on health. Although the work might be considered suspect by some due to the sponsoring organizations, the SSCRPC found the work to be well-researched, complete, scholarly and informative.

After reviewing the extant peer-reviewed literature on wind turbine sound and possible health effects (drawing from the research listed in *PubMed* as well as other sources), the panel reached agreement on three key points which are fundamental to their analysis (Colby et al., p. 5-1):

- *There is nothing unique about the sounds and vibrations emitted by wind turbines.* That is, the accumulated knowledge about sound and its affect on human health is as applicable to the consideration of sound generated by wind turbines as it is to any other sound source.

- *The body of accumulated knowledge about sound and health is substantial.* While the body of knowledge specifically related to sounds generated by wind turbines may be more limited, a great amount of work has been done concerning sound and health more generally, as well as under specific conditions. This work is accessible by those studying the effect of wind turbine generated sound on human health and is relevant in assessing any health risks. The SSCRPC found that one of the difficulties in assessing the work of those suggesting that the sound of wind turbines results in health problems, is that they often do not appear to be conversant in the existing literature concerning sound. This leads to weak theoretical conceptualizations and a misunderstanding of pervious work.

- *The body of accumulated knowledge provides no evidence that the audible or substantial sounds emitted by wind turbines have any direct adverse physiological effects.*

Based upon the available evidence and the scientific community's understanding of the effects of sound on human health, the panel concluded (p. 5-2) that:

- The sound from wind turbines does not pose a risk of hearing loss or any other adverse health effect in humans.

- Subaudible, low-frequency sound and infrasound from wind turbines, often cited by wind facility opponents as cause for additional regulation, do not present a risk to human health.

- Some people (with several studies indicating about 5% of the population: Pedersen at al., 2009; Pederson and Waye, 2004; Pederson and Waye, 2007) may be annoyed at the presence of sound from wind turbines, but annoyance is not a pathological entity.

- A major cause of concern about wind turbine sound is its fluctuating nature. Some may find this sound annoying, a reaction that depends primarily on personal characteristics as opposed to the intensity of the sound level.

This is consistent with Bastasch's conclusion that the, "…research suggest that modern turbines do emit infrasound, but at levels below the minimum threshold of perception for most of the population, and well below the threshold for any adverse effects" (2006, p. 10).

Regarding Vibroacoustic Disease and Wind Turbine Syndrome

Although the trend in the research to date does not show any negative physiological effect arising from the sound generated by wind turbines, since some wind farm opponents contend that sounds from wind turbines produce certain specific diseases and syndromes, the SSCRPC thought it relevant to specifically address these claims.

In reviewing the studies offered by those contending that wind turbines have a negative physiological effect on humans, the SSCRPC found that they are generally limited in method (e.g., lack of control groups or involve no epidemiological studies), anecdotal (e.g., based upon a single case study, newspaper reports, or self-reports from households already pre-disposed to an outcome), misunderstand sound fundamentals (e.g., the relationship between sound pressure, frequency and sound exposure), or have not been subjected to peer review or are incomplete (see for example: Frey and Hadden, 2007; Harry, 2007; Pierpont, 2008). This includes work supporting what has been termed "vibroacoustic disease" (VAD), which is largely drawn from previous studies of health effects associated with aircraft technicians, and "wind turbine syndrome" (WTS), which has a less secure founding in previous studies of sound effect.

The Colby report specifically looked at the issues surrounding VAD and WTS and commented:

> Some reports have suggested a link between low frequency sound from wind turbines and certain adverse health effects. A careful review of these reports, however, leads a critical reviewer to question the validity of the claims for a number of reasons, most notably (1) the level of sound exposure associated with the putative health effects, (2) the lack of diagnostic specificity associated with the health effects reported, and (3) the lack of control group in the analysis. (Colby et al., 2009, p. 4-5)

Vibroacoustic disease has primarily been proposed by two Portuguese researchers as being caused by wind turbines (Alves-Pereira and Castelo Branco, 2007a, 2007b, 2007c, 2007d). In looking specifically at the research offered to support the contention that the low-frequency or infrasound from wind turbines causes VAD, among other criticisms of this work the study found (Colby et al., pp. 4-5 – 4-8):

- No epidemiological studies that evaluated risk of VAD from exposure to infrasound, which is contended to cause it. In fact studies of workers subject to much higher levels of infrasound than that produced by wind turbines have not shown a risk of VAD. Some of the cases used to support the contention that wind turbines produced VAD were based upon extremely limited samples (e.g., single households who were self-selected complainants), and at levels similar to common urban environments.

  The SSCRPC believes that if VAD is a result of exposure to the levels of low-frequency or infrasound generated by wind turbines, one should find it present in the general population living in urban environments. However this is not the case, leading one to conclude that the contention is faulty.

- The likelihood is remote in light of the much lower vibration levels in the human body itself. This may be due to various researchers (e.g., Pierpont,

2009) not clearly understanding the difference between sound vibration, assumed to result from inaudible low-frequency sounds, and mechanical vibration (see Colby et al., pp. 3-9 – 3-11).

- The studies that the VAD concept was based upon were reporting on much higher frequency and sound pressure levels than those produced by wind turbines; for example, studies of aircraft technicians.

  The SSCRPC believes that this most likely explains why VAD is not found in urban environments and would not be found near wind energy facilities; the frequencies and sound pressure levels in these environments are simply not great enough to result in a physiological effect.

Wind turbine syndrome has been hypothesized and primarily promoted by Pierpont (2009) and appears to be based upon two contentions. The first is that low levels of airborne infrasound from wind turbines (in the range of 1 to 2 Hz) directly affects the vestibular system (the sensory system that contributes to balance and spatial orientation), and the second is that low levels of such sound (4 to 8 Hz) also enter the lungs via the mouth and then vibrates the diaphragm, transmitting vibrations to the internal organs of the body. Pierpont contends that the combined effect of these two vibrations, “sends confusing information to the position and motion detectors of the body, which in turn leads to a range of disturbing symptoms” (Colby et al., p. 4-8).

The Colby report finds that the first contention results from a misunderstanding of a study related to the vestibular system by Todd and others (2008) that was conducted at much higher frequencies than infrasound (100 Hz and above) and was not addressing air conducted sound. Colby and his fellow researchers note:

> There is no credible scientific evidence that low levels of wind turbine sound at 1 to 2 Hz will directly affect the vestibular system. In fact, it is likely that the sound will be lost in the natural infrasonic background sound of the body. (Colby et al., p. 4-9)

They also find little support for the second Pierpont contention, writing that it is:

> ...equally unsupported with appropriate scientific investigations. The body is a noisy system at low frequencies. In addition to the beating heart at a frequency of 1 to 2 Hz, the body emits sounds from blood circulation, bowels, stomach, muscle contraction, and other internal sources. (Colby et al., p. 4-9)

They also point out that low sound levels from outside the body do not cause a high enough excitation within the body to exceed internal body sounds:

> Pierpont refers to papers from Takahashi and colleagues on vibration excitation of the head by high levels of external sound (over 100 dB). However, these papers state that response of the head at frequencies below 20 Hz was not measurable due to the masking effect of internal body vibration (Takahashi et al., 2005; Takahashi et al., 1999). When measuring chest resonant vibration caused by external sounds, the internal vibration masks resonance for external sounds below 80 dB excitation level (Leventhall, 2006[b]). (Colby et al., p. 4-9)

This, according to the analysis, means that Pierpont's second contention is false. Additionally the Colby study points to methodological problems associated with the Pierpont research and notes that its "symptoms" have been better explained and addressed previously within the context of "annoyance" rather than being a substantive syndrome that would indicate a fundamental threat to health (Colby et al., pp. 4-9 – 4-10).

As noted in closing comments related to Pierpont's hypothesis, "[i]n ordinary life, most of us are exposed for hours every day to sounds louder than those experienced at realistic distances from wind turbines, with no adverse effects" (Colby, et al., p. 4-11), and that at this time "wind turbine syndrome" and associated contentions[2] must be considered "unproven hypotheses (essentially unproven ideas) that have not been confirmed by appropriate research studies, most notably cohort and case control studies. However, the weakness of the basic hypotheses makes such studies unlikely to proceed" (Colby et al., p. 4-12).

Others, such as Dr. Amanda Harry, a physician in the United Kingdom, have made similar claims concerning harmful effects arising from low-frequency and infrasound. However Bastasch (p. 9-10) finds methodological problems with Harry's work similar to those mentioned above, and also points out how some claims arise from a misunderstanding of the work of others – such as Leventhall – or the taking of their findings out of context. In summary, Bastasch (p. 10) specifically points to a paper by Levethall (2005) in which he concludes that specialists in wind turbine sound have their work cut out for them in educating the public that infrasound from wind turbines is not a problem, and that while low frequency sounds may be audible under certain conditions, the regular 'swish' of a wind turbine is not low frequency sound.

Annoyance

If the sound generated by wind turbines (particularly low-frequency and infrasound) does not have a detrimental effect on *human health*, and our review of the literature seems to indicate that it does not, that does not mean that it has no effect on *humans*.

As noted previously, wind turbines *do* make sounds and those sounds can be perceived as noise and be a nuisance to some. In brief, some people find the sound of wind turbines *annoying*. While annoyance is not an adverse health effect or disease of any kind, it is a possible result of wind turbine operations and is worthy of consideration.

As Colby and colleagues note (p. 3-13), annoyance is a subjective response to many types of sounds that varies among people and cannot be predicted with a sound meter, as the same type of sound may elicit different reactions from different people. The dominant feature leading to annoyance reported by Colby and colleagues as related to wind farms was the sound of the blades "swishing", which had also been found in previous studies (Colby et al., p. 3-15).

However, the level of annoyance reported as arising from the sounds made by the turbines may simply be masking other, more relevant, annoyance factors, and acting as a surrogate for

---

[2] Beyond "wind energy syndrome", Pierpont has also suggested the existence of what she calls "visceral vibratory vestibular disturbance" or VVVD. To Pierpont VVVD is a distinctive feature of WES, but appears to us to be something of a re-theorization of WES to allow it to address psychological features that might be associated with "annoyance" rather than something more physiological; though she contends it has a physiological basis. VVVD is addressed and critiqued in Colby, et al., pp. 4-10 – 4-11.

them. Pederson and Waye (2004), for example, found that attitudes toward visual impact, wind turbines in general, and sensitivity to noise were also related to the way people perceived noise from the turbines. A 2009 study of 725 people living in the vicinity of wind turbines in the Netherlands (Pederson et al., 2009) found the sounds from wind turbines to be more annoying than several other environmental sources at comparable sound levels, and also noted a strong correlation between noise annoyance and negative opinion of the impact of wind turbines on the landscape.

As Knopper and Ollson describe this research (2011, p. 5), visual impact has come out as a stronger predictor of noise annoyance than the wind turbine noise itself, and this predictor may even be a result of the residents' expectations about the type of landscape in which they live. Reviewing Pederson and Waye's work, they note a difference between rural and suburban areas. As Pederson and Waye (2007) report, their results indicate, "that the wind turbine noise interfered with personal expectations in a less urbanized area…pointing towards a personal factor related to the living environment" (see Knopper and Ollson, p. 5). This includes aesthetic aspects and the view that wind turbines are "intruders".

The SSCRPC emphasizes the relevance of this result. Correlation is not causation. That is, simply because the study found sound annoyance correlated with negative opinions of wind turbines on the landscape does not mean that sound annoyance led to the negative opinion. It is just as possible that those with a negative opinion of wind turbines were more sensitive to the noise they create, leading to a greater reporting of annoyance[3].

This finding is echoed in the literature review conducted by Knopper and Ollson (2011), who write:

> Conclusions of the peer reviewed literature differ in some ways from those in the popular literature. In peer reviewed studies, wind turbine annoyance has been statistically associated with wind turbine noise, but found to be more strongly related to visual impact, attitude to wind turbines and sensitivity to noise. To date, no peer reviewed articles demonstrate a direct causal link between people living in proximity to modern wind turbines, the noise they emit and resulting physiological health effects. If anything, reported health effects are likely attributed to a number of environmental stressors that result in an annoyed/stressed state in a segment of the population. (p. 1)

This may be why the results reported by Pederson and others suggest that while the wind turbine sound is easily perceived and is annoying to a small percentage of people (5% at 35 to 40 dB on an A-weighted scale, and 18% at 40 to 45dBA). Other studies have found similar results, one indicating 10% annoyance at sound levels of 40dB or more and another indicating about 8% (Pederson, 2008).

As Bastasch and colleagues describe the situation:

> It has long been known that annoyance from noise is not related to the noise levels themselves. For example, a meta-analysis of 136 community noise studies (Fields, 1993)…found that noise annoyance is only weakly related to noise levels. This analysis found that annoyance is related to:

[3] See, for example, Pederson et al., 2009, for further support of this notion, and it will be addressed again in this report in light of a more recent analysis by the Commonwealth of Massachusetts.

- Noise sensitivity
- Fear of danger from the noise source
- Attitudes toward noise prevention
- Attitudes about the importance of the noise source
- Annoyance with non-noise aspects of the noise source.

Even at low noise levels, a small percentage of people in these studies were highly annoyed. (Bastasch et al., 2006, pp. 8-9)

Annoyance may have indirect physiological effects worthy of consideration. Protracted annoyance may generate stress, which can result in such outcomes as sleep disturbance, what has been termed the “nocebo” effect (the opposite of the “placebo” effect, this is a worsening of mental or physical health based upon a fear or belief in adverse effects), anxiety, and other stress-related psychological responses (Colby et al., pp. 4-1 – 4-5). However, it is important to understand that, “no differences were reported among people who were ‘annoyed’ in contrast to those who were not annoyed with respect to hearing impairment, diabetes, or cardiovascular disease” (Colby et al., 2009) leading one to again conclude that the sound from wind turbines does not increase the risk of detrimental physiological health effects.

Massachusetts Study

A study conducted following the original release of this *SSCRPC Information Brief* appears to confirm the findings in the SSCRPC’s initial review of the literature related to the effect of sound generated by wind turbines. This study was done by an independent panel of experts brought together by the Massachusetts state departments of Public Health and Environmental Protection. The study (Ellenbogen et al., 2012) considered a number of public health and safety concerns with the intention of identifying any scientifically documented or potential connection between wind energy turbines and health.

As to sound generated by wind turbines, and “based on the detailed review of the scientific literature and other available reports and consideration of the strength of the scientific evidence” (Ellenbogen et al., p. ES-4), the panel found that wind turbines can produce unwanted sound (noise) during operation, but that the nature of the sound depends upon the design of the wind turbine. Propagation of the sound is primarily a function of distance, but can also be affected by the placement of the turbine, surrounding terrain, and atmospheric conditions (p. ES-4 – ES-5).

As to health effects, they reported that, “[m]ost epidemiological literature on human response to wind turbines relates to self-reported ‘annoyance,’ and this response appears to be a function of some combination of the sound itself, the sight of the turbine, and attitude towards the wind turbine project” (p. ES-5.) The expert panel also found: (i) that there was little epidemiological evidence suggesting an association between exposure to wind turbines and annoyance; (ii) insufficient evidence to determine whether there is an association between noise from wind turbines and annoyance independent from the effects of seeing a wind turbine and vice versa; and (iii) limited evidence suggesting an association between wind turbine noise and sleep disruption (pp. ES-5 – ES-6.)

Regarding sleep disruption, the panel found that it is possible that noise from some wind turbines can cause sleep disruption, as a:

> …very loud wind turbine could cause disrupted sleep, particularly in vulnerable populations, at a certain distance, while a very quiet wind turbine would not likely disrupt even the lightest sleepers at the same distance. But there is not enough evidence to provide particular sound-pressure thresholds at which wind turbines cause sleep disruption. (p. ES-6)

So, "[w]hether annoyance from wind turbines leads to sleep issues or stress has not been sufficiently quantified", and "[t]here 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" (p. ES-6; italics in the original). The reader should note that their findings are similar, if not identical, to the findings associated with "Annoyance" we previously reported in the section above.

The Massachusetts group also addressed "wind turbine syndrome" and similar claims. They report that, "[c]laims that infrasound from wind turbines directly impacts the vestibular system have not been demonstrated scientifically. Available evidence shows that the infrasound levels near wind turbines cannot impact the vestibular system", (p. ES-6). And related to this, find that, "[t]here is no evidence for a set of health effects, from exposure to wind turbines that could be characterized as a 'Wind Turbine Syndrome' ", (p. ES-7).

In concluding their remarks related to sound effects on public health, the Massachusetts panel found that the strongest epidemiological study suggests that there is not an association between noise from wind turbines and measures of psychological distress and mental health problems, and that other evidence they reviewed did not suggest an association with pain and stiffness, diabetes, high blood pressure, tinnitus, hearing impairment, cardiovascular disease, and headache/migraine. (p. ES-7).

Again, these results appear to support findings previously noted in the SSCRPC's review of the research literature.

In Conclusion

While the SSCRPC staff does not have particular expertise in sound science and the physiological effects that sound might have on the human body, we found that the literature on the effect of wind turbine sound on human health to be relatively straight forward and approachable. Since methods for assessing the internal and external validity of research are known to us, it was also possible to come to at least some general understanding of the scholarly rigor demonstrated in the various papers reviewed.

Based upon this review, it is our current opinion that there is no reliable empirical evidence that the sounds – including low-frequency and infrasound – generated by wind energy facilities is a threat to public health and safety. Our opinion seems to be confirmed by the much more extensive review and analysis of the literature conducted for the Commonwealth of Massachusetts.

In addition, it appears that the trend in the literature is toward not finding an association between sound produced by wind turbines and matters of public health. Aside from our own limited review, two major reviews of the scientific literature have been done in recent years

(Colby et al., in 2009, and Ellenbogen et al., 2012), both reaching similar conclusions. We find this particularly relevant in considering the necessity for changing land use regulations or increasing the wind energy conversion system setback requirements found in the County's current zoning ordinance.

We do find that the sounds generated by wind turbines can be annoying, and that this can have an effect on surrounding residents. However this finding is somewhat mitigated by the research indicating that this occurs in a relatively small percentage of the population, a portion of that group have a general sensitivity to sound and therefore could be affected by many possible land uses (including agricultural), and that in some cases this annoyance may be a surrogate of other aspects of the wind energy facility that they dislike, rather than the sound itself.

While there may be other public policy considerations that would lead to changes in the ordinance, we do not believe that the evidence exists to suggest that it should be changed due to fear that the sounds generated by wind turbines present a danger to human health. We believe that this finding is consistent with other studies on this subject found in the published literature.

This Report Prepared by E. Norman Sims, SSCRPC, Executive Director

References

Alves-Pereira, M., and Castelo Branco, N.A.A. (2007a). Public health and noise exposure: the importance of low frequency noise. *Proceedings of the Inter-Noise 2007 Conference.* Istanbul, Turkey: International Institute of Noise Control Engineering and the Turkish Acoustical Society. Aug. 28-31, 2007.

Alves-Pereira, M., and Castelo Branco, N.A.A. (2007b). In-home wind turbine noise is conducive to vibroacoustic disease. *Proceedings of the Second International Meeting on Wind Turbine Noise.* Lyon, France: International Institute of Noise Control Engineering - Europe. Sept. 20-21, 2007.

Alves-Pereira, M., and Castelo Branco, N.A.A. (2007c). The scientific arguments against vibroacoustic disease. *Proceedings of the Inter-Noise 2007 Conference.* Istanbul, Turkey. International Institute of Noise Control Engineering and the Turkish Acoustical Society. Aug. 28-31, 2007.

Alves-Pereira, M., and Castelo Branco, N.A.A. (2007d). Infrasound and low frequency noise dose responses: contributions. *Proceedings of the Inter-Noise 2007 Conference.* Istanbul, Turkey. International Institute of Noise Control Engineering and the Turkish Acoustical Society. Aug. 28-31, 2007.

Bastasch, M., van Dam, J., Sondergaard, B., Rogers, A. (2006). Wind turbine noise – an overview, *Canadian Acoustics*, 24 (2). Pp 7-15.

Colby, W.D., Dobie, R., Leventhall, G., Lipscomb, D.M., McCunney, R.J., Seilo, M.T., and Sondergaard, B. (2009). *Wind Turbine Sound and Health Effects: An Expert Panel Review.* Prepared for the American Wind Energy Association and the Canadian Wind Energy Association.

Ellenbogen, J.M., Grace, S., Heiger-Bernays, W.J., Manwell, J.F., Mills, D.A., Sullivan, K.A., Weisskopf, M.G., Santos, S.L. (2012). *Wind Turbine Impact Study: Report of Independent Expert*

Panel. Prepared for the Massachusetts Department of Environmental Protection and the Massachusetts Department of Public Health. Boston.

Fields, J.M. (1993). Effect of personal and situational variables on noise annoyance in residential area, *Journal of Acoustical Society of America*, 93 (5). Pp. 2753-2763.

Frey, B.J., and Hadden, P.J. (2007). *Noise Radiation from Wind Turbines Installed Near Homes: Effects on Health.* www.windturbinenoisehealthhumanrights.com.

Hayes McKenzie Partnership. (2000). *Noise from Wind Turbines: The Facts.* Prepared for the British Wind Energy Association. www.bwea.com.

Harry, A. (2007). *Wind Turbines, Noise and Health.* Unpublished.

Jakobsen, J. (2004). Infrasound emissions from wind turbines. *Proceedings of the 11th International Meeting on Low Frequency Noise and Vibration and Its Control:* Maastricht, Netherlands. MultiScience Publishing Company.

Knopper, L.D., Ollson, C.A. (2011). Health effects and wind turbines: a review of the literature, *Environmental Health*, 10 (78). pp. 1-10.

Leventhall, G. (2004). *Low Frequency Noise from Wind Turbines with Special Reference to the Genesis Power Ltd. Proposal, near Wailuku, NZ.* Geoff Leventhall: Surry, UK.

Leventhall, G. (2005). How the “mythology” of infrasound and low frequency noise related to wind turbines might have developed, *Proceedings of the First International Meeting on Wind Turbine Noise: Perspectives for Control*, Oct. 17-18. Berlin, Germany.

Leventhall, G. (2006a). Infrasound from wind turbines: fact, fiction or deception. *Canadian Acoustics*, 34(2), pp. 29-36.

Leventhall, G. (2006b). Somatic responses to low frequency noise. *Proceedings of the 12th International Meeting: Low Frequency Noise and Vibration and its Control.* Bristol, UK: Journal of Low Frequency Noise and Its Control, International Institute of Noise Control Engineering.

O’Neal, R.D., Hellweg, J.R., Lampeter, R.M. (2011). Low frequency noise and infrasound from wind turbines, *Journal of Noise Control Engineering*, 59. Pp. 47-53.

Pederson, E., Bakker, R., Bouma, J., and van den Berg, F. (2009). Response to noise from modern wind farms in the Netherlands. *Journal of the Acoustical Society of America,* 126. Pp. 634-643.

Pederson, E., and Waye, K. P. (2004). Perception and annoyance due to wind turbine noise: a dose-response relationship, *Journal of the Acoustical Society of America*, 116. Pp. 3460-3470.

Pedersen, E., and Waye, K.P. (2007). Wind turbine noise, annoyance and self-reported health and well-being in different living environments, *Journal Occupational Environmental Medicine*, 64. Pp. 480-486.

Pederson, E., Waye, K.P. (2008). Wind turbines – low level noise sources interfering with restoration?, *Environmental Research Letter*, 3. Pp. 1-5.

Pederson, T.H. (2008). Low-frequency noise from large wind turbines: a procedure for evaluation of the audibility for low frequency sound and a literature study. *DELTA Report EP-06.*

Pierpont, N. (2008). *Wind Turbine Syndrome: Draft Article*. www.ninapierpont.com.

Pierpont, N. (2009). *Wind Turbine Syndrome: A Report on a Natural Experiment*. Pre-publication draft. http://www.windturbinesyndrome.com/wp-content/uploads/2009/03/ms-ready-for-posting-on-wtscom-3-7-09.pdf.

Rogers, A.L. (2005). *Infrasound and Psychoacoustics*. National Wind Coordinating Committee meeting on Wind Turbine Siting Issues, Dec. 2, 2005. Washington, DC.

Rogers, A.L., Manwell, J.F., and Wright, S. (2006). *Wind Turbine Acoustic Noise*. Renewable Energy Research Laboratory, University of Massachusetts at Amherst. Amherst, MA.

Takahashi, Y., Kanada, K., Yonekawa, Y., and Harada, N. (2005). A study on the relationship between subjective unpleasantness and body surface vibrations induced by high-level low-frequency pure tones, *Industrial Health*, 43. Pp. 580-587.

Takahashi, Y., Kanada, K., Yonekawa, Y., and Maeda, S. (1999). A pilot study on human body vibration induced by low frequency noise, *Industrial Health*, 37. Pp. 28-35.

Todd, N., Rosengren, S.M., and Colebatch, J.G. (2008). Tuning and sensitivity of the human vestibular system to low frequency vibration, *Neuroscience Letters*, 444. Pp. 36-41.

Van den Berg, G.P. (2004). Do wind turbines produce significant low frequency sound levels? *Proceedings of the 11th International Meeting on Low Frequency Noise and Vibration and its Control*. Maastricht, Netherlands. Pp. 367-376.

Wagner, S., Bareib, R., and Guidati, G. (1996). *Wind Turbine Noise*. Springer: Berlin, Germany.

Wind and Hydropower Technologies Program, U.S. Dept. of Energy (2009). *Wind Turbine Sound*. http://www.windpoweringamerica.gov/ne_issues_sound.asp.

The Springfield-Sangamon County Regional Planning Commission (SCRPC) serves as the joint planning body for Sangamon County and the City of Springfield, as well as the Metropolitan Planning Organization for transportation planning in the region. The Commission prepares area-wide planning documents and assists the County, cities, and villages, as well as special districts, with planning activities

The Commission has 17 members including representatives from the Sangamon County Board, Springfield City Council, special units of government, and six appointed citizens from the city and county. The Executive Director is appointed by the Executive Board of the Commission and confirmed by the Sangamon County Board.

The Commission works with other public and semi-public agencies throughout the area to promote orderly growth and redevelopment, and assists other Sangamon County communities with their planning needs. Through its professional staff, the SSCRPC provides overall planning services related to land use, housing, recreation, transportation, economics, environment, and special projects. It also houses the Sangamon County Department of Zoning which oversees the zoning code and liquor licensing for the County.
