LEARNING FROM EVIDENCE OF SOUND EXPERIENCED FROM WIND TURBINES

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1. INTRODUCTION

Wind turbine sound regulations are generally based on A-weighted sound levels, reducing the effect of frequencies outside 500-11,000 Hz by more than 3dB. Wind turbine sound predominates at lower frequencies where human audibility and physiological response still exists. Regulatory limits are not intended to pose annoyance, yet placement of wind turbines near homes is reported to cause significant annoyance, sleep deprivation, and adverse effects.

Large industrial wind turbines produce a unique sound signature, cyclical in both amplitude and frequency, from a source that varies in a cyclical pattern of position and distance relative to listening points, since the principal sound source arises from turbulence following the trailing edge of the outer quarter of the blades, an annular ring 75 to 100 metres in diameter, a noticeable variation in relation to the 500 to 3000 metres from turbines to impacted receptors.

This paper relates factors identified previously by others to facts determined by recording and analyzing the differences in samples of sound over a full year at sites in a wind power development of 110 Vestas V82 turbines in Ontario's Bruce County, located acceptably to provincial regulators for spacing from wind turbines, and at control sites in the same environment at greater distances from the turbines.

2. METHODS

This paper will identify key findings related to the subject of sound of wind turbines identified by others at the Fourth International Meeting on Wind Turbine Noise held in Rome, in April 2011, and the 161st Meeting of the American Acoustical Society, in Seattle, in May 2011. Then, this paper will outline how the research conducted in this study relates to the issues raised by others.

2.1 Key Findings from Recent Conferences

No rigorous epidemiological study has been conducted by any jurisdiction, which would be necessary to show a direct relationship between the sound produced by wind turbines and health effects, as was done to show the suspected but unproven link between smoking and health.

The need for research to show direct clinical evidence was identified by Greg Tocci[1], as the requirement for policy makers to move sound from annoyance, to a health effect. Tocci commented that this had resulted in a 30-year period of "benign neglect" of sound in the US, although he noted work in progress in Europe sponsored by the WHO with regard to "The burden of disease from environmental noise" at conferences in 2005, '07, and '11, chaired by Rohku Kim.

Papers presented have shown wind turbines do produce a distinctive sound[2,3]. Sound levels similar to those experienced by people living at approved setbacks from wind turbines has been shown to produce direct and adverse impacts on blood pressure (systolic and diastolic), on heart rate, and on respiration rate[4]. The link between wind turbine sound and sleep disruption was noted by researchers[5,6,7].

Further, the evidence from qualified sleep researchers[5,8,9] shows "annoyance" of sleep disruption from any cause can result in delayed sleep onset, recalled awakening (for periods of >30 seconds), and perhaps most importantly, in repetitive non-recalled arousals (for periods of < 30 seconds). These, sleep researchers state, can have adverse impacts of fatigue, decreased performance, increased accident rates, cardio-vascular impacts, and diabetes.

Salt presented[10] a physiological link between the response of the ear to low frequency sound unrelated to audibility. Specifically, the response of the outer hair cells of the ear, and the response of the fluid in the inner ear to infrasound may be enhanced, and Salt stated it is premature to dismiss the influence of wind turbine noise on the ear. Literature identifies the link between the response of the fluid in the inner ear and motion sickness and disruption to balance.

A number of presenters discussed the psychoacoustic linkage between the "soundscape" and annoyance. George Luz presented a tutorial[11] identifying that noise sensitivity (about 1 in 5 people) does not decrease over time, while it may increase. Luz concluded with a statement about airport siting, "it may be premature to infer that decision makers at the studied airport *planned to cause harm to minority groups. Less invidiously,* decision makers might try to please important constituents (such as the median voter), without thinking through the possibility that decisions to help median voters may cause harm to others." The applicability to wind turbine siting was chilling.

A number of papers showed the consequence of not having a basis for noise standards when developing public policy. The conflict between potential community benefit (such as jobs) was often traded by municipal governments[11,12,13] against occasional "annoyance", and there was great diversity between what was acceptable in one community versus another. This clearly identified that a government policy that gives total control of the siting of wind turbines to individual municipalities is inadequate to protect citizens.

Many speakers identified the necessity to listen to the noise sources to identify special characteristics they possess, not just to record level as the "quality" impacts annoyance. The conferences identified a number of ways in which the sound

from wind turbines is unique, and how the particular characteristic of the sound makes wind turbines more annoying. Richarz[14], presented on audible low-frequency wind turbine sound. He noted that auto-correlation of measured wind turbine sounds exhibits distinct, periodic "low frequency" pulses that when propagation effects are accounted for, result in an audible swoosh. McCabe[15] reported he had identified elevated levels of amplitude modulation with a diurnal pattern, more noticeable at night, which might be why wind turbines are more annoying than other sources. di Napoli[16] reported on very strong amplitude modulation from monitored turbines and that it is not possible to conclude that amplitude modulation decreases with distance, as do simple assessments. Lundmark[17] reported that it was not possible to compare wind turbine sound to beach noise or waterfalls, and explained why turbine sounds were disruptive, rather than calming.

2.2 The Method of the Current Research

Digitized sound samples were recorded at 6 nearby sites in the environment of a wind power development during all seasons of the year. The method is explained in detail and detailed results are presented in the reference[18].

3. RESULTS

This study showed that receptors at setbacks approved by Ontario regulators for wind turbines experienced sound levels 20 dB higher at all octaves up to 1000 Hz compared to a site in the same environment 5000 metres from the wind turbines any time the turbines were operating, even at very low power. The study also identified frequency and amplitude changes in the sound from wind turbines, which make them even more noticeable; much like the wee-woo of emergency vehicle sirens makes them noticeable. The work also showed that actual sound readings taken by the acoustical consultant of the proponent of a wind farm in response to a complaint identified that sound levels exceeded the predicted value fully half of the time at midnight, were 3dB or higher above the predicted value at least 25% of the time at midnight, and were correlated to turbine power, not ambient wind speed.

4. DISCUSSION AND CONCLUSIONS

While "direct health effects" from the sound from wind turbines has not been shown by epidemiological study, clear links to adverse health effects from increases in sound level, roughness, etc. are shown, increasing blood pressure (systolic and diastolic), heart rate and respiratory rate.

The link between sound with special characteristics (e.g. cyclical amplitude and frequency modulation) and annoyance is known. The link between annoyance and sleep disturbance is known. The link between sleep disturbance and adverse health effects is well established. While some 1 in 5 people are more "noise sensitive" than others, no evidence suggests "attitude training" will erase this. The consequence of setting regulations without adequate basis, or using local regulation without protective guidance is clear. Evidence shows the low frequency dominance of wind turbine sound, and it's human perception.

This paper has shown evidence that sound level at receptor locations approved in Ontario is some 20 dB higher at all octaves up to 1000 Hz compared to sites in the same environment distant from wind turbines. The increase in sound is shown to be due to the wind turbines, not ambient wind. Cyclical amplitude and frequency shift of the sound is shown to be related to the wind turbines.

Thus, the link between the sound from wind turbines, to annoyance, hence sleep disturbance, and hence to adverse health effects is established, but yet no epidemiological studies have been conducted to prove the direct health effect. Still, to ignore concerns identified and to continue to site wind turbines by current regulations would seem to be imprudent, if not negligent.

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