

## **Wind Turbines and Adverse Health Effects: Turbine Noise or a State of Mind?**

### **Summary**

Wind energy generation is promoted as one contribution to a lower carbon future. This has some merit. However, the way that it is being introduced into Ontario is creating annoyance, stress and anxiety in the rural residents among whom the turbines are imposed. The problem is that the turbines are, to a large extent, being shoe-horned into rural residential areas of long standing, particularly along the shore-lines of the Great Lakes. This problem is compounded by the lenient regulations for the siting of turbines, the stranglehold over the approval process by the provincial government and the inability to date of the provincial government to test compliance with its own regulations.

It is accepted by experts for the industry, the government and for those living among the turbines that turbines cause annoyance and sleep disturbance; in turn these can lead to other adverse health effects. Where there is difference is in the cause of the annoyance, sleep disturbance and stress. Government and industry consultants claim first that there is no direct cause of adverse health effects and second that the major cause of the annoyance and sleep disturbance is the attitude towards the wind turbines. Concerning the first claim, the World Health Authority acknowledges that annoyance and sleep disturbance are adverse health effects and can lead on to other serious problems. Concerning the second claim, these consultants point to the large field studies of Eja Pedersen and her colleagues.

This report takes a close look at the field studies and shows clearly that the cause of the annoyance is the turbine noise. It is found that there is a linear dependence of annoyance upon the turbine noise at a residence. It is also found that there is no correlation between annoyance and the resident's attitude towards the visual aspect of the turbines. If wind energy is to have a future in Ontario, or anywhere, then stricter noise regulation is needed.

### **Background**

There is no doubt that for a significant fraction of people living among modern wind turbines there are adverse health effects. In general, these are indirect stress effects resulting from chronic annoyance and sleep disturbance and deprivation associated with living among the turbines. The adverse health effects include headaches, difficulty concentrating, irritability, fatigue, dizziness or vertigo, nausea, tinnitus, anxiety, heart ailments and palpitation.

Although the obvious cause of the annoyance and sleep deprivation is the turbine noise, apologists for the wind industry also cite the negative attitude of turbine neighbours to the visibility of the turbines. To bolster this view, which throws the source of the

adverse health effects onto the psychological state of the resident rather than onto the physical noise generated by the turbines, the apologists cite the work of Pedersen et al. published in a peer-reviewed journal<sup>1</sup>. This paper also summarizes the earlier parallel study in Sweden<sup>2</sup>. The following quotations are representative of the apologists' statements:

**(Ontario) Chief Medical Officer of Health Report (May 2010):**

“Studies in Sweden and the Netherlands have found direct relationships between modelled sound pressure level and self-reported perception of sound and annoyance. The association between sound pressure level and sound perception was stronger than that with annoyance<sup>3</sup>. The sound was annoying only to a small percentage of the exposed people; approximately 4 to 10% were very annoyed at sound levels between 35 and 45 dBA. Annoyance was strongly correlated with individual perceptions of wind turbines. Negative attitudes, such as aversion to the visual impact of wind turbines on the landscape, were associated with increased annoyance, while positive attitudes, such as direct economic benefit from wind turbines, were associated with decreased annoyance.”

Note the technique used here:

a) The association between annoyance and sound pressure level is less than that between sound perception and sound pressure level. As noted in foot-note 3, the second correlation is one to one.

b) Whether deliberately or not, the number of very annoyed is misquoted: for those respondents to the survey who do not benefit economically the percentage very annoyed was between 6 and 19% in the range 35 to 45 dBA.

However, the authors binned the respondents into 5 groups: Do not notice; notice but not annoyed; slightly annoyed; rather annoyed and very annoyed. Then then collected the latter two groups and classified them as annoyed. The percentage annoyed was 15 to 27% in the range 35 to 45 dBA.

c) Having diminished the correlation between annoyance and sound pressure level the author then goes on to stress a strong correlation between annoyance and attitude to the wind turbines. This deliberate inversion of the facts is discussed below.

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<sup>1</sup> E. Pedersen, F. van den Berg, R. Bakker and J. Bouma, “Response to Noise from Modern Wind Farms in the Netherlands”, J. Acoust. Soc. Am. **126**, 634 – 643 (2009). See also the report which formed the basis for the peer-reviewed paper: F. van den Berg, E. Pedersen, J. Bouma and R. Bakker, “WINDFARMperception: Visual and Acoustic Impact of Wind Turbine Farms on Residents” (2008). <http://www.epaw.org/documents/WFp-final-1.pdf>

<sup>2</sup> E. Pedersen and K. Persson Waye, “Wind Turbine Noise, Annoyance and Self-Reported Health and Well-Being in Different Living Environments” *Occup. Environ. Med.* **64**, 480 – 486 (2007).

<sup>3</sup> This sentence is irrelevant: sound perception results from the sound pressure level; there is bound to be a direct correspondence!

**L. D. Knopper and C. A. Ollson<sup>4</sup> (Consultants working for Algonquin Power Corp. and Stantec Consulting Engineering).**

“We found that conclusions of the peer reviewed literature differ in some ways from the conclusions of the studies published in the popular literature. What both types of studies have in common is the conclusion that wind turbines can be a source of annoyance to some people. In the peer reviewed studies, wind turbine annoyance and some reported health effects (e.g., sleep disturbance) have been statistically associated with wind turbine noise especially when found at sound pressure levels greater than 40 dBA, but found to be more strongly related to subjective factors like visual impact, attitude to wind turbines in general and sensitivity to noise.”

**Paul Masotti<sup>5</sup>**

“My question is this: would this discussion (annoyance associated with wind turbine noise) be taking place if the wind turbines were the same size as telephone poles?”

**W. David Colby et al.<sup>6</sup>**

Conclusion #4: “A major cause of concerns about wind turbine sound is its fluctuating nature. Some may find this sound annoying, a reaction that depends upon personal characteristics as opposed to the intensity of the sound level”

**The Analysis**

Pedersen et al. presented the results of a 2007 field study in the Netherlands and related it to an earlier Swedish study. From a list of almost 18,000 addresses of residents living in proximity to turbines almost 2000 were selected for the field study. The response rate was 37%. All turbines were 500 kW or larger; however, this cut-off is small in comparison to the 2.3 MW and larger turbines that are now being installed. The surveys were constructed to hide the purpose of the field study<sup>7</sup>. The respondents were grouped according to the predicted turbine noise level at their home: <30, 30-35, 35-40, 40-45 and >45 dBA for a wind speed at 10 m of 8 m/s. For reference, the Ontario noise limit at 8 m/s is 45 dBA<sup>8</sup>.

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<sup>4</sup> L. E. Knopper and C. A. Ollson, “Health Effects and Wind Turbines: A Review of the Literature”, *Environmental Health* **10**, 78 (2011).

<sup>5</sup> Letter to the Kingston Whig Standard, Feb. 9<sup>th</sup>, 2012

<sup>6</sup> W. D. Colby, R. Dobie, G. Leventhall, D. M. Lipscomb, R. J. McCunney, M. T. Seilo, B. Søndergaard, “Wind Turbine Sound and Health Effects: An Expert Panel Review” prepared for American Wind Energy Association and Canadian Wind Energy Association (2009).

<sup>7</sup> The title of the survey (translated into English) was “Study of the Perception of the Living Environment”. The purpose of the survey was:

“To provide knowledge of the perception of wind turbines by people living close to wind farms; To evaluate human responses to audio and visual exposures from wind turbines and to give insight in(to) possibilities to mitigate the local impact of wind farms.”

<sup>8</sup> However, the reality is that the noise limit of 40 dBA at a wind speed of 6 m/s will determine the setback. See the 2008 Ministry of the Environment wind turbine noise guidelines.

This report is concerned with distinguishing between turbine noise and visual attitude to wind turbines as the trigger for annoyance and hence adverse health effects. It is based upon the data base assembled by Pedersen et al<sup>1</sup>. The table shows a sub-set of the data base. The first row is the predicted sound pressure level at the home, based upon the ISO 9613-2 methodology and checked against other models. The second row shows the percentage of respondents with economic benefits from the turbines. Additionally it is reported that these respondents had some control over the turbines, including one report of being able to shut down the turbine when annoyed. The third row shows the percentage of respondents for whom the turbines were visible. The next two rows show the percentages annoyed, for the whole sample and for those without economic benefit. Again, following Pedersen et al.<sup>1</sup> the number annoyed includes those rather annoyed and those very annoyed. The final three rows are those with a negative attitude towards the look of the turbines (negative visible attitude). First, for the whole sample, then for those without economic benefit assuming that those with economic benefit do not have a negative attitude. To derive this number the present author divided the percentage for the complete sample by the fraction without benefit. The final row is based upon the assumption that those without a view of the turbines will not have a negative visual attitude! The reality will be somewhere between the final two rows.

Predicted SPL (dBA)	<30	30-35	35-40	40-45	>45
Economic Benefit (EB) (%)	2	3	10	34	67
Wind Turbine Visible (%)	35	60	90	89	100
Annoyed (%)	2	7	18	18	12
Annoyed (%) No EB	2	7	20	25	28
NVA (%)	33	36	45	39	20
NVA (%) No EB, estimated	34	37	50	59	61
NVA (%) No EB, turbine visible, est.	97 (?)	62	56	66	61

Figure 1 shows, for those without economic benefit, the dependence of the fraction of respondents annoyed as a function of the predicted noise level at their homes. The five noise bands correspond to <30, 30-35, 35-40, 40-45 and >45 dBA.

The clear picture that emerges is that annoyance of residents is linearly related to the noise at the residence. **That is, turbine noise causes annoyance.**

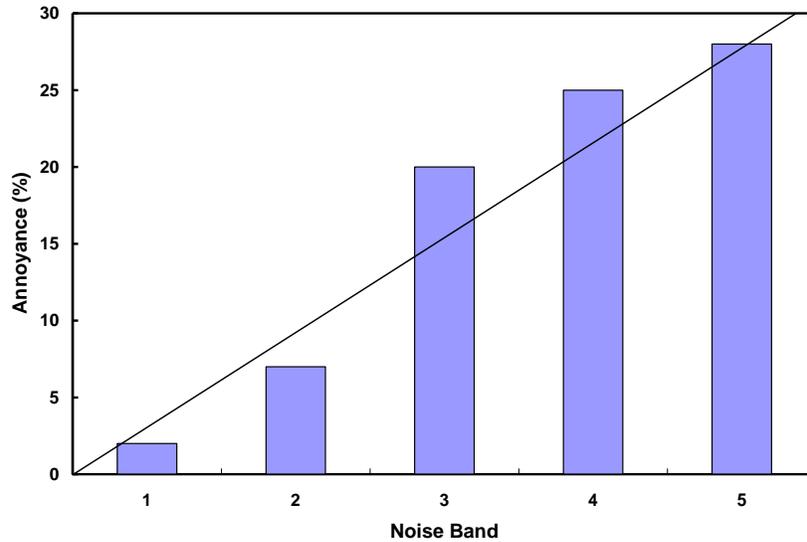


Figure 1. Dependence of Those Annoyed upon the Sound Pressure Level

Figure 2 shows the estimated relationship between a negative visual attitude and the annoyance experienced by the respondents without economic benefit. For the lower curve, no account was taken of whether a turbine was visible to the respondent. For the upper curve it was assumed that only those for whom a turbine was visible would have a negative visual attitude. The reality will lie between the two curves. **It is clear that there is not a linear relation between annoyance and a negative visual attitude toward turbines.** Consider those in the lowest noise band (<30 dBA): Just 2% are annoyed and yet between 33% and 97% have a negative attitude to the look of the turbines. About 60% of those living in proximity of turbines have a negative visual attitude without regard to how close to the turbines they live or how noisy the turbines are at their homes.

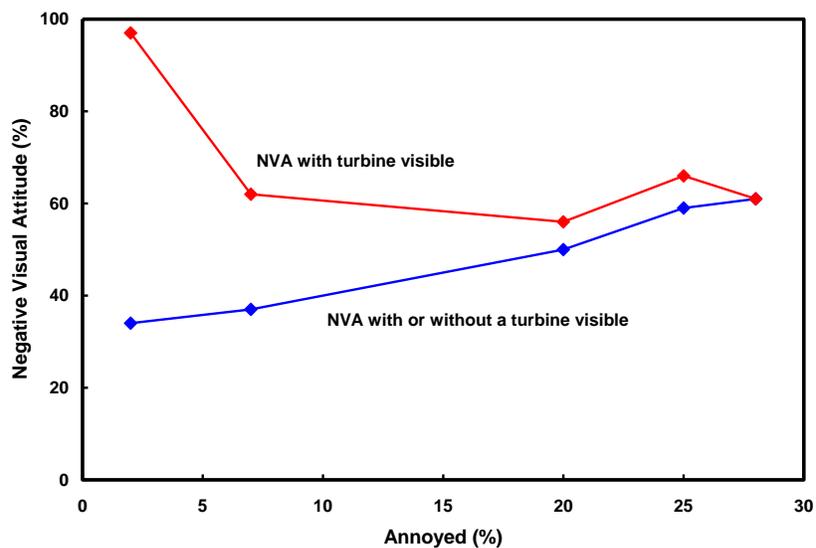


Figure 2. The Relation between Negative Visual Attitude (NVA) and Annoyance.

Much has been made of this negative attitude to wind turbines and their visual impact on residents who are having the turbines shoe-horned among them. There is indeed a negative attitude and who can blame them. The turbines are an intrusion into a rural or semi-rural area, they cause property values to plummet and they have an impact on wild-life. However the large field studies conducted by Pedersen and colleagues provide no support for these attitudes causing annoyance, sleep deprivation and consequent adverse health effects.

It is the noise that causes the annoyance. The turbine noise is significantly more annoying than noise at the same sound pressure level arising from road, rail and air traffic<sup>1</sup>. The reason is that the turbine noise is incessant, is amplitude modulated, is predominantly low frequency as the higher frequency components are absorbed in the atmosphere, is enhanced by the blades turning in turbulent air (from atmospheric or wake turbulence), and is under-estimated by current prediction algorithms. The problem of low frequency noise will only get worse as the turbines get larger. Møller and Pedersen<sup>9</sup> demonstrate a downward shift in frequency of one-third octave on going from less than 2 MW turbines to larger turbines in the range 2.3 to 3.6 MW. Low frequency noise can penetrate into homes and be amplified by resonance effects.

Finally, it is often asserted that adverse health effects are a North America phenomenon and that the Europeans have long accepted wind energy generation. These two large studies from Sweden and the Netherlands demonstrate that this is not true. To a large extent the push for off-shore wind projects in Europe is driven by the backlash against more on-shore projects. Where the Europeans are ahead is in research, not only into better turbine design but also into understanding and reducing aerodynamic noise and into noise propagation modelling. They understand that turbine noise is a problem that needs to be faced up to. Germany is still developing on-shore wind energy but has a 35 dBA night-time noise limit to better protect its rural residents.

John Harrison<sup>10</sup>. March 2012

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<sup>9</sup> H. Møller and C. S. Pedersen, "Low Frequency Noise from Large Wind Turbines", J. Acoust. Soc. Am. **129**, 3727-3744 (2011).

<sup>10</sup> Credentials:

Career: PhD (Leeds, 1964); Post-doctoral Fellow (Cornell 1964 – 67, Sussex 1967 – 69); Faculty at Queen's University (1969 – 2002); presently retired.

Wind Turbine Noise: Presentations made to community groups; Member of the Ministry of the Environment Stakeholder Focus Group on Wind Turbine Noise Regulations; Invited talk given at the International World Wind Energy Conference held in June 2008 in Kingston, Ontario and paper accepted for the conference proceedings; Invited talk and paper presented on wind turbine noise at the annual conference of the Canadian Acoustics Association in October 2009; Invited talk presented at the International Symposium on The Global Wind Industry and Adverse Health Effects in October 2010, with the paper published in Bulletin of Science, Technology and Society 31, 256 (2011).