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NOISE POLLUTION FROM WIND TURBINES - Living with amplitude modulation, lower frequency emissions and sleep deprivation

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Abstract

Although wind energy has a role to play in the renewable energy sector, when wind turbines are sited too close to people's homes, the noise pollution has dire consequences on those who live nearby. The authors, who live within 930 metres of the nearest wind turbine of a wind farm, document their personal experiences that underscore research findings on the adverse impact of wind turbine noise on human well-being, as well as present the results of sound data measured by acousticians at their home. The paper describes the nature of the noise – with its pulsating character, the vibrations felt by the body, and its intrusiveness, as well as the impact of the noise on them physically and psychologically. Most serious is the sleep deprivation and the ensuing adverse effects, and the inability to pursue or sustain normal family and social activities. Indeed, the authors recently abandoned their home because of the unremitting character of the noise and its adverse impact on their lives. The authors note that rural environments, which are attractive to the wind energy industry, are especially challenging because background noise is low or virtually non-existent, particularly at night. Yet current UK guidelines, set by the Government in 1997 with significant input by the wind energy industry, offer no respite to those who live near wind turbines or those communities analysing current wind turbine applications from developers. The authors suggest that the wind energy industry would gain credence by acknowledging that there are gaps in the ability to

predict with accuracy whether wind turbines will create noise pollution. Moreover, the industry could avoid the issue altogether by placing wind turbines further from homes. This solution would simultaneously contribute to the credibility of the wind energy industry while protecting the public's health and their right to the amenities of their homes.

Introduction

We are Julian and Jane Davis. We live on a farm on the Fens in Lincolnshire, England, an area known as South Holland. In May 2006, the construction of a wind farm consisting of eight 2 megawatt turbines, each approximately 100 metres tall, was completed, located south from us with the nearest turbine 930 metres away. Even though we live on the Lincolnshire Fens, our house is well-shielded by mature trees and large agricultural buildings, so for most of the year, we cannot actually see the turbines. As soon as the wind farm became operational, we noticed subtle acoustic abnormalities. At this point we assumed NO connection with the turbines. But as a few days passed, the full extent of the noise pollution from the wind farm became apparent.

We had supported wind energy and the construction of wind farms and were naïve enough to believe the literature issued by the developers. We had thought that normal background noise would mask any emissions from the wind turbines and that if there was not enough wind to make any background noise (e.g., trees rustling), then the turbines would not have enough wind to operate. We had also done limited research on complaints against wind farms; besides, many objections were based on the visual effects on the landscape. To us at this time, any visual impairment caused by the erection of the wind farm was a fair trade for the supposed environmental benefits.

We are presenting this paper to illustrate the devastating effects of wind turbine noise pollution when wind farms are sited too close to homes or otherwise inappropriately sited. We have since learned that even engineers and designers within the wind energy industry cannot accurately predict how the wind turbines interact within a given environment and climate, even with the most current computer modelling.¹

(Barbara J Frey, BA, MA and Peter J Hadden)

Moreover, the developers certainly do not publicise that noise pollution from wind farms is a significant issue. As we have learned, it is an issue that cannot and should not be dismissed because of its varied, unpredictable, and sometimes elusive yet damaging nature.

It may be said that wind turbines create pollution during their construction, and that is true of any industrial construction, but once in operation, wind turbines may continue to emit unprecedented levels of pollution in the form of sound pressure waves, some of which are interpreted by humans as noise. Having been exposed to over 10,000 hours of sound pressure waves emitted by a wind farm sited 930 metres from our home we have a reasonable grasp of the “nuisance” caused by the varied emissions of wind turbines.

To date many people have been somewhat dismissive about wind farm noise pollution. The combination of the inability of the general public to understand the mechanisms, by which sound pressure waves with various characteristics are emitted from turbines, and the varied and sometimes subtle nature of the noise pollution they create, make it very easy for those who wish to diminish its importance. In fact, for many people, merely standing at the base of a turbine and hearing a gentle swish of the blades comprises all the research that they consider necessary to form an opinion.

We had welcomed the construction of a nearby wind farm naively believing wind turbines to be a legitimate alternative energy source. Yet, for some, wind turbines seem to hold a near religious or romantic value (as opposed to simply being large industrial generating units), and this attitude appears to influence some of the research and media coverage to date.

Within the UK the guidance on wind farm construction has not kept up with the developments of wind turbines. The techniques chosen by the Government to predict and assess noise pollution from wind farms, published in ETSU-R-97, are now unreliable and inappropriate, and extrapolations to increasingly taller turbines appear not to hold true in a number of cases. ² (Bowdler) This, in terms of noise pollution control, has led to a situation where developers use this to their advantage. For under UK guidance if the amplitude of the emitted noise modulates at short periodic

intervals it is almost impossible to breach the imposed conditions (no matter what the peak dB level is).

The result, under certain circumstances is no control or limit at all. In the UK, if the noise of a wind farm was replicated electronically next to a domestic dwelling, under nuisance law an enforcement notice would be issued to stop it. Yet if the very same noise comes from the actual wind farm, then the UK guidance (ETSU-R-97) is used to impede nuisance law that in other circumstances protects the public.

To compound this our house is set in secluded, quiet countryside, and probably being the quietest, nearest property to the wind farm, is surrounded by trees and large agricultural buildings. An approximation to our normal background noise with the turbines (but not in operation) would be around 18 – 20dB (A) (this was only recorded after the wind farm was constructed). The difference between our normal rural quietitude and peaks of the amplitude of aerodynamic modulation occurring between 55 and 66 dB(A) are therefore far more noticeable. The “normal” operating noise levels from the turbines are double our ambient noise at 36 - 40 dB (A).

Turbine noise is only measured as background noise, but the effect on human life and health can be devastating. Studies carried out on the health of communities living around existing wind farms are starting to uncover some unpleasant facts. Lower frequency sound pressure waves emitted by some turbines have been connected with similar physiologic changes associated with Vibro-Acoustic Disease (VAD)³ (Ref – Mariana Alves-Pereira & colleagues). Noise can adversely affect mood and health, for example, it can cause measurable changes of physiological stress (like cortisol). There is a substantial body of research that documents the ill-effects of noise and sleep deprivation on human health.

There are other aspects that shape peoples perception of the nuisance caused by noise pollution from wind farms. ⁴Pedersen (2005), reports of the possibility of a complex relationship between audio and visual stimuli, for example, the blade motion and/or shadow flicker. Preconceptions of the impact of turbines on the landscape may influence sensitivity to noise from a wind farm. Conversely, the visual aspect of the turbines may just remind people of the devastating effects they have on their lives. Remarkably the solution is so simple: site wind turbines away from homes.

Methodology

Noise pollution can be viewed as comparative only to an extent, and can be put down to personal perception, annoyance and irritation. A better aim is to identify the noise pollution and correlate it with influencing factors and to explain how the combination affects day to day living by:

- 1) Identifying and naming specific repeatable noise characteristics. This has been done without reference to other published works so as to maintain our personal perspective on the noise pollution.
- 2) Identifying any relationship of noise source to point of perception.
- 3) Identifying any physical factors affecting the perception and annoyance of noise pollution emitted from the wind farm.
- 4) Describing and recording the effects that noise pollution from the wind farm have on day to day living.

All observations are based on personal perception. Where indicative values are given for noise levels these are generally given as “real time” values for approximate comparative guidance (although they are based on actual data recorded at our home).

Results

SOUND PRESSURE WAVES EMITTED BY WIND FARMS (ACOUSTIC ARTEFACTS)

- 1) **Whoomph**: one of the louder aerodynamic noises emitted, it modulates like the sound of a slow helicopter blade rotating. With varying amplitude of this aerodynamic modulation it can take on a slight whipping sound. Normal sound levels of the Whoomph is approximately 45 to 55 dB (A). Indoors this results in a pulsating THUD or beat, that is both heard and felt.
- 2) **Swish**; general sound of the blade whipping the air (35-45dB (A)).
- 3) **Roar/Grind/(WD40)** like a speeded up recording of the sea or intense distant road noise (35 – 45 dB(A))
- 4) **Hum**: (perceived at approximately 80 – 250 Hz) very subtle but impossible to get away from, exceptionally penetrating.

- 5) **Amplitude Modulation (AM):** Most dramatically effects the Whoomph, synchronisation of noise from the wind farm causing reinforcement of the waveform – adds 5 to 10dB (A) to the level of the Whoomph.

PERCEPTIONS

- 1) For Swish and hum the amplitude is proportional to distance from turbines. The hum appears to cross from audio to physical. It is almost as if you can feel the noise as a sensation in the ear. The amplitude of the swish decreases greatly when the observer moves a short distance from the turbines. The amplitude of the hum does not and is detectable at more than 2000 metres from the turbines.
- 2) Whoomph, Roar and AM projects AWAY from the turbines, i.e the nearer you get the less the effect or amplitude. Once you get closer than approximately 600 metres detection becomes difficult. Conversely, the three types of emission can easily be detected up to 1500 – 2000 metres from the wind farm.
- 3) Because the source of the noise pollution is so large and high it engulfs or encompasses affected properties.
- 4) The sensation is felt in the body as well as being “heard” in the conventional sense. For instance when putting ear defenders on to work on a car with a defective alarm, the defenders blocked out the car alarm sound, but the turbine “noise” could be clearly heard and felt even with the defenders in place. Within our home (as was) the fabric of the house insulates against audible sounds but you can still sense the rhythm of the turbines. This is particularly noticeable when trying to relax or sleep.

FACTORS THAT EMPHASISE TURBINE EMISSIONS

- 1) Shelter – trees tend to filter out other sounds, making the sound of the turbines clearer.
- 2) Reflective Surfaces – Buildings reflect the sound, increasing the annoyance and making the enveloping of the area even more complete.
- 3) Insulation from other sounds (double glazing, wall insulation, ear plugs etc) leads to greater selection for lower frequency sound pressure waves as they

have a much greater ability to penetrate and are practically impossible to protect against in a domestic situation.

- 4) Wind direction: All effects are worst when the wind is from a southerly direction, blowing through the wind farm toward our home. Whoomph and AM only occur with this wind direction. However, the other aspects of the noise are always present to some extent regardless of wind direction. Lower frequency emissions vary little in perceived amplitude irrespective of wind direction or turbine operation.
- 5) Stable air conditions associated with temperature inversion on summer evening, i.e., still air and quiet at ground level but strong wind at 100 metres above ground level. ⁵ (Van den Berg).

THE EFFECT ON LIVING

Noise Characteristics influence:

- 1) Sleep
- 2) Rest
- 3) The ability to enjoy the amenity that is your home (or was)
- 4) Health issues
- 5) Loss of value to home because prospective purchasers will avoid noisy, unhealthy locations (unrelated to landscape value)
- 6) Concentration making using complex equipment potentially dangerous.
- 7) Impairing cognitive ability, which may have adversely affected Jane and our daughter's ability to achieve high grades in her exams.
- 8) Social lives, e.g. it is no longer possible for our daughter to have "sleep-overs".
- 9) Moods,,,, constant tiredness leads to increased irritability and feelings of despair, and feelings of inability to cope with normal day to day activities.

Sleep

Much has been written about the alleged fact that noise from wind turbines does not cause you to wake up – but that the noise may prevent you returning to sleep once awake. Many acoustic reports make reference to the fact that external ambient noise such as “the wind rustling the leaves in the breeze”, the trickle of a nearby stream, or a vehicle passing on a distant road, will mask the noise of the turbines.

Well. We are here to tell you that this is not always the case. I suppose that in our situation, we have no convenient trickling stream – where we live in the flat East Anglian Fens, the dykes or drains don't do “trickling”, also where we live there are no roads that vehicles pass along that could wake us up – and the leaves mask any background noise, which leaves only the pure wind turbine “Acoustic Artefacts” to impinge on our previously undisturbed sleep. As humans sleep in cycles usually of about four hours, then what we have found – repeatedly, is that our brains have subconsciously heard the noises coming from the turbines – or possibly, our bodies are responding to the disturbance, because one hears with more than one's ears, sound is processed by the brain, and our auditory processing operates even while sleeping. When we are in a lighter phase of sleep – and thus we get startled awake – in much the same way that you do when your alarm clock goes off when you have set it wrongly for 3.44 am – and having been shocked awake like that – it is almost impossible to go back to sleep again.

Two or three weeks of this happening night after night leads to symptoms of sleep deprivation – used in some cultures as a form of torture.

Rest

If a body can't rest then a body can't work...or function properly – and that is what we found. A tired mind and body become more prone to accidents, not ideal in any circumstance but dangerous on a farm. The peculiar noises that the wind turbines emit can not only be heard, they can also be felt by the body, and thus trying to rest becomes impossible. We tried: fans, white noise machines, sleeping tablets, red wine and ear plugs. The latter again masks background noises but allows the low frequency that we get to penetrate so that it feels part of your body and the beat – the pulsation -- that is slightly faster than our human hearts beat, means that you feel as if you are constantly trying to get your heart to catch up with this external rhythm that is felt by the body rather than heard ... so rest is impossible.

The ability to enjoy the amenity that is your home (or was)

The biggest problem with the noises from the wind turbines is that they are so unpredictable. You can plan a BBQ for an evening where the weather looks appropriate, warm and sunny, and the evening will be still with no wind at ground

level and then – just as the food is ready comes the THUMP, THUMP, THUMP that indicates AM is back ... and when that happens, it's really difficult to even find out if someone wants a sausage or a beef burger – and conversations become stilted as the noise draws people's attention and diverts and distracts them. We now know that these weather conditions – so right for BBQs or sitting out enjoying the rural quietitude – are a result of low level stable atmospheric conditions but strong winds at 100 meters above ground. ⁶(Van den Berg) In these so-called stable atmospheric conditions, AM is disturbing and disruptive.

Because we have farm buildings that the noise can reflect off, during a night when the noise is really bad, you can even get a harmonic going in the farmyard with all buildings pulsating and vibrating – sometimes causing some people with existing ear disease to feel nauseous.

The problem became so bad last summer 2006 – the noise forced us to evacuate our home and to sleep out with friends, on bed settees, spare beds, settees, hotels by main roads – anywhere that gave us some peace away from the noise and low frequency sensations. The hum, incidentally, does not travel with us!

Health Issues.

Other speakers at this Conference will present scientific evidence about the definite links between wind turbine noise pollution and health, in a far more scientific form than we can.

What we do know is that right from the commencement of the wind farm operations we all started suffering from headaches and a horrible sensation in the ears. Friends staying with us said it was “as if someone is using a pipe cleaner to clean out my ears”, and other descriptions include someone “blowing down my ear drums”.

House guest's complained of being suddenly awoken at 4am with a sound that they described as being equivalent to a motorcycle revving outside the bedroom window. But there was no bike, and they found this noise from a unseen source very eerie and unsettling. We experienced ear infections – something that certainly in my case I had managed to live 50 years without, stomach upsets, general feelings of jitteriness and depression. We were permanently tired, our cognitive skills were impaired, and our ability to concentrate on anything for even a short period of time was dramatically

reduced. For our daughter studying for vital AS exams this was extremely challenging, and for Jane also studying for her Diploma it was disconcerting, and interfered greatly with the processes needed to write complex papers. When watching television the noise was distracting because the “THUMP”, “THUMP” could be heard alongside, and significantly interfered. Because of its nature, the ability to follow conversations is impaired, yet alone understanding the story line.

It was difficult to fall asleep, or stay asleep, and when you woke – it was always with a sense of not having slept.

The only good effect that we can report is that of having completely flat lawns for the first time in three decades, the moles having left any of our land within 200 metres of any building within 3 days of the wind farm having started operations. However we too have found the low frequency hum impossible to live with, and eventually we too left our home.

WHEN A NOISE ANNOYS.

Finally, in December 2006, we decided that we could not carry on with the half life that we had been living and that we needed a more permanent resolution than the itinerant traipsing from friend to friend with sleeping bags and pillows. We effectively rented a “sleeping house”. Erroneously, we thought that by then, the Authorities were going to take action to resolve our awful situation soon. We had got better – nae even expert – at predicting when the worst noises would occur, so that we could flee our home.

On May 27th, this year – almost exactly one year after the wind farm commenced operating – we effectively abandoned our home for the purposes of living in it. We now know that we are the fourth family in the UK to take what we consider to be drastic and devastating action, that is, we have been forced from our homes.

Some of you will have been at the Institute of Acoustics meeting in Swaffham earlier this year where reference was made to our plight, and we know that some of you disbelieved so much that you found the situation funny.

All I ask of you who disbelieve as you listen or read this: Do you really think we would leave our home and use our savings to rent a house 5 miles away just for fun? If you are a disbeliever, come and stay in our home, with your families, and experience for yourselves the inhumane circumstances imposed on my family by the wind turbine developers.

Think of us when you go home, have your dinner, perhaps a glass of wine ... and then go upstairs to your own beds in the comfort and peace of your own home, and spare a thought for the families whose lives have been torn apart when wind turbines are built too close to people's homes.

We know that we can "hear" the noise in our home under the right set of circumstances because the low frequency noise has an impulsive, pulsating characteristic. We accept that it is not clear with low-frequency noise if we are hearing or feeling it or some combination of both stimuli. Because of the impulsive nature of the acoustic low-frequency energy being emitted, there is an interaction between the incident acoustic pulses and the resonances of our home which serves to amplify the stimuli creating vibrations as well as redistributing the energy higher into the audible frequency region. Thus the annoyance is often connected with the periodic nature of the emitted sounds rather than the frequency of the acoustic energy.

Oh – and just as a reminder – we can't actually see the turbines from our house at all and we didn't object to the wind farm as we believed all the reviews that said "Modern Wind Turbines are Quiet".....

MOST RECENT FINDINGS.

The DTI has recently investigated the incidence of low frequency noise and Aerodynamic Modulation at wind farms in the UK. It is hoped that the full report will be available before the conference.

A summary of the report concludes that the incidence of AM at wind farms is very limited in terms of the number of people affected.

So those attending the windturbinenoise2007 Conference should consider themselves privileged to be able to listen to the experiences of one of the very few families that are affected by AM, though the numbers are higher for those disturbed by wind turbine noise more generally. (Though if that rare, one does wonder about entire conferences devoted to wind turbine noise, and research articles within the industry consumed with the same issue.)

The report also concluded that the causes of AM are not fully understood and that AM cannot be predicted using current state of the art methods.

Conclusions

Many aspects of windfarm noise pollution are a direct and obvious intrusion to day to day life. Sleep deprivation, with its associated health deficits is probably the worst aspect and the facilitator of many other problems.

The lower frequency sound wave pollution from the turbines appears unstoppable in terms of penetration through buildings and the likely health effects of such pollution are only now becoming evident.

We support the recommendations of the French Academy of Medicine, and the UK Noise Association, that industrial wind turbines should not be sited near homes, with a separation of **at least 2km**, though in some circumstances, a greater separation may be necessary to protect the health, well-being, and the amenities of one's home for those living nearby.

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