centre for sustainable energy

Common concerns about wind power (2nd edn)

Chapter 15
Infrasound, 'wind turbine syndrome' and other health concerns

This is one of a series of chapters of evidence-based analysis drawing on peer-reviewed academic research and publicly funded studies.

For other chapters, see
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Centre for Sustainable Energy, June 2017

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Common concerns about wind power (2nd edn)

Chapter 15
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The first edition of Common Concerns about Wind Power was published in 2011 to provide factual information about wind energy, in part to counter the many myths and misconceptions surrounding this technology.

Since 2011, much has changed in the legal and economic sphere, and a second edition became necessary. Research has been carried out for this edition since 2014. Therefore, this edition is formatted as a series of individual chapters available for download at www.cse.org.uk/concerns-wind-power-2017

All chapters written and researched by Iain Cox.

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Chapter 15

Infrasound, 'wind turbine syndrome' and other health concerns

Summary

Within the last decade, the development of wind farms around the world has been accompanied by a profusion of health concerns that have been the cause of much contention between advocates and opponents of wind power. The longest-running, and perhaps most contentious of all, is the subject of low-frequency noise normally considered inaudible to the human ear, commonly known as infrasound. The role of infrasound as a hidden causative agent behind 'wind turbine syndrome' – the reported ill-health suffered by some individuals living near wind farms – has garnered significant support, but this movement has been based largely on the promotion of a small group of self-publicising researchers and anti-wind protest groups.

The theory that infrasound from wind turbines might be causing real, physiological effects on nearby residents has so far failed to produce any empirical evidence or, indeed, even a plausible mechanism. The persistence of 'wind turbine syndrome' as a reason for rejecting wind farm developments seems to be more closely linked to the expectation of negative health effects from proposed and existing wind power facilities, an expectation that has been driven by largely unfounded reports from media and campaign groups about potential health impacts. This has entrenched the idea of wind turbines as one more modern malaise that contributes to a variety of non-specific health problems. This has parallels with other modern health worries, such as concerns over the presence of electromagnetic fields, where there is a common pattern of sufferers' symptoms and associated psychological distress being attributable to the 'nocebo' effect rather than any physical stimulus.

Since the latter half of the 2000s, claims about the potential health impacts of wind turbines have surfaced more frequently due to the continuing coverage that 'wind turbine syndrome' receives, despite consensus in the peer-reviewed literature that there is no evidence such a thing exists. The repeated propagation of baseless claims obscures the much-better understood issues surrounding environmental noise generated by wind turbines that is audible. The continued distraction also hinders treatment for the small number of individuals who genuinely suffer from anxiety, stress and attendant health problems brought on by the perceived existence of negative environmental agents with no discernible physical cause.

What is this based on?

With the rapid proliferation of utility-scale wind power since the 1990s, there has been controversy over the potential health impacts of modern, large wind turbines. This has led to repeated calls to investigate evidence that the operation of wind turbines leads to impaired health in those living close by, despite evidence demonstrating that the vast majority of claims are unfounded.[1–3] Early opposition groups objecting to the installation of wind farms frequently highlighted the risk of harm to bird and bat populations, or the risks posed by shadow flicker and the level of audible noise emitted by rotating turbines. (These issues are addressed in their own chapters elsewhere in this guide – see chapters 11, 13 and 14). Since the early 2000s, infrasound (low-frequency noise below 20 Hz) and electromagnetic fields from wind turbines have been touted as having 'hidden effects', with concerns about infrasound in particular culminating in the invention of 'wind turbine syndrome', which posits that a variety of non-specific health effects can be attributed directly to the operation of wind turbines. [3–6] Added to this is the more recent emergence of suggestions that there is a link between wind turbines and autism. This chapter will address these three issues.

In 2009, drawing on a series of case studies from 10 families with a total of 37 subjects, Nina Pierpont (a paediatrician in New York state) attributed the following symptoms to low frequency sound emissions from wind turbines: sleep disturbance, headache, tinnitus, other ear and hearing sensations, balance and equilibrium disturbances, anxiety, nausea, irritability, energy loss, motivation loss, memory and concentration disturbances. The author of this case series grouped these symptoms together under the umbrella of 'wind turbine syndrome'. These findings have been self-published in a book marketed by the author.[7] Although Pierpont's publication gained immediate popularity with anti-wind groups, the attribution of health problems to the existence of nearby wind turbines had started to gain traction in opposition

movements several years earlier, around 2002 and 2003.[4] While these early reports mentioned specific concerns such as shadow flicker, many other serious but non-specific symptoms came to light, such as increased stress, sleep disturbance and need for prescription medicines.[8] A similar report by a UK doctor was released in 2007 (although it is credited as being work that began in 2003), which suggested that the myriad symptoms reported by residents were due to the 'complexity' of the noise and vibration generated by wind turbines.[9] A group of researchers studying technicians and aircraft crews subjected to loud industrial noise – far in excess of what a wind turbine produces and with very prolonged exposure – coined the term 'vibroacoustic disease',[10] although this condition was never recognized by any other group despite several decades of research.† [6,11] Despite the absence of any demonstrated link between vibroacoustic disease and noise emissions from wind turbines, the same vibroacoustic disease researchers lent their backing to the idea that low-frequency noise emitted by wind turbines caused a host of health problems.[11,12] This announcement helped sanction within anti-wind groups the concept that low-frequency noise, especially subaudible infrasound, was the causative agent of various non-specific health issues reported by respondents living near to wind farms, even though evidence has shown that personal attitudes to wind turbines is a better predictor of these symptoms than any objectively measured infrasound.[2,5,13]

In a similar fashion to the infrasound theory, a focus on health impacts due to electromagnetic fields produced by wind turbines has led in recent years to an increase in negative reporting, raising the expectation that health impacts will occur once a wind farm is operational.[14,15] This has been seized upon by anti-wind groups, and has translated into greater anxiety over wind farm proposals and an increase in health issues being cited as a reason for organised opposition.[4,14,16] It has been shown that these negative expectations manifest as a 'nocebo' effect. Rather like a placebo has a positive effect on a person's condition despite there being no physical agent present that might produce such an outcome, a nocebo can induce a psychological or psychosomatic effect that is detrimental to a person's health. The reporting of non-specific health problems attributed to electromagnetic fields has been shown to be independent of actual exposure, but greatly influenced by negative reporting, a phenomenon also seen in controlled studies where subjects are exposed infrasound from wind turbines.[17,18]

† Henning von Gierke, a noted researcher in the field of noise and health, remarked that vibroacoustic disease 'remains an unproven theory belonging to a small group of authors and has not found acceptance in the medical literature.' Von Gierke H, Mohler SR. Aviat. Space Environ. Med. 2002;73(8):828–9.

More recently, the refusal of planning permission for a wind farm near to the home of autistic twins has led to the emergence of concerns that wind farms can cause or exacerbate the symptoms of autistic spectrum disorders.

What is current evidence?

Low-frequency noise and infrasound

Sound propagates as a pressure wave through vibrations in the air. The energy intensity, or amplitude, of the pressure wave emitted is measured in decibels (dB), which is a useful measure of how humans perceive the loudness of a sound. The dB scale is a logarithmic scale, such that an increase from 0 dB to 10 dB is a 10-times increase in energy intensity, from 0 dB to 20 dB is a 100-times increase in loudness, and so on. Note, however, that a person with normal hearing would consider an increase from 10 dB to 20 dB to be 'twice as loud' even though the energy intensity has increased tenfold. The number of vibrations per unit time – the frequency – is given in Hertz (Hz). The range of frequencies at which sound is audible to the human ear is enormous, between 20 and 20,000 Hz, but the human ear is most sensitive to frequencies between 1,500 and 4,000 Hz, where even very soft sounds (0 dB or thereabouts) are discernible.

Sound at frequencies 20–250 Hz is classed as low-frequency noise. Below the 20 Hz threshold is *infrasound* – low frequency sound outside the normal range of human hearing. However, this definition is more to do with practicality and convention; hearing is a continuous process that does not simply terminate at 20 Hz.(19,20) It is accepted that frequencies below 20 Hz are indeed audible, with subjects hearing frequencies as low as 4 Hz in a sound chamber and 1.5 Hz through headphones.[19,21] Thus, the concept of 'infrasound' as a sharp delineation between what can and cannot be heard is not correct. It has been suggested that is reasonable to consider audible low-frequency noise to extend as low as 5 Hz.[19)]

What is important to note is that these frequencies only become audible, that is, detectable by the sensory structures of the inner ear and transmitted to the auditory cortex in the brain, at high sound pressure levels (e.g. 79 dB for 20 Hz, 107 dB for 4 Hz).[6,22] Studies that expose subjects to infrasound at very high sound pressure levels (120 dB or more) have shown that the auditory cortex is the only region that processes the incoming sound, and infrasound at subaudible levels (90 dB or less) does not stimulate this area of the brain.[23] This supports earlier work showing that sound pressure waves are detected by the cochlear across the low-frequency and infrasound range.[24] In other words, low-frequency noise and infrasound is received by the inner ear and processed by the brain in the same way as sounds in higher frequency ranges, but the lower the frequency the louder the sound must be to be perceptible.

Although the sound pressure level required for auditory perception becomes very high as the frequency decreases, a small percentage of the population have a lower hearing threshold for low-frequency noise, with the most sensitive 10th percentile possessing a threshold of more than 6 dB compared to the median.[25] Furthermore, despite loss of sensitivity to higher frequencies with increasing age, it has been observed that hearing thresholds in the low-frequency noise and infrasound range may be a few decibels lower for some 50–60 year-olds compared with young adults.[6]

The effects of noise on human health and activities have been studied for many decades. Work on the effects of low-frequency noise largely began with the Apollo space programme, which focused on the need to ensure physiological harm was avoided when workers were routinely exposed to very loud environments.[19] In less extreme circumstances, environmental noise in modern society originates primarily from traffic (road, rail and air), industrial workplaces and the urban environment.[26] Unfortunately, due to the misrepresentation of some early research, combined with common misconceptions about the audibility of low-frequency noise (mentioned above), the term 'infrasound' quickly entered the public consciousness as an entity associated with various scare stories about hidden, or silent, health impacts.‡ This prompted complaints of low-frequency noise and lurid Cold War myths of the power of infrasonic weapons.[19] Investigation of complaints involving low-frequency noise having a detrimental effect on sufferers inevitably fails to objectively detect levels of noise – the source remains mysterious, even if the psychological distress is very real.[25,27] It is conjectured that non-acoustic sources may be responsible for sufferers' symptoms, and failure to isolate the cause of distress leads complainants to blame a more tangible source, such as low-frequency noise or infrasound from gas pipelines, boiler rooms, or, in recent years, wind turbines.[6,19] In some cases, electromagnetic waves are blamed, and the presence of electromagnetic fields are themselves frequently attributed with causing many of the same non-specific health effects as infrasound.[6,28] These are considered later in this chapter.

Infrasound, and low-frequency noise in general, is increasingly cited as a particular property of wind turbine sound that makes them uniquely capable of causing health disorders.[5] With this argument arising more and more in cases opposing wind farm development, there have been an increasing number of studies on the noise generated by wind turbines. As already discussed, it is possible for infrasound to be audible if the sound pressure level is high enough. Indeed, infrasound can very quickly reach annoying or distressing levels when it passes into the audible threshold;[21] but, all studies of infrasound produced by wind turbines show that levels are significantly below audible unless the listener were located less than 100 metres from the nearest turbine.[3,5,13,19,20,29–34]

Overall, the case for 'wind turbine syndrome' as put forward by Pierpont and propogated by groups opposing wind farms presents very weak evidence for anything akin to a definable syndrome. Following several years of campaigning after a wind farm was proposed next to her town in Malone, New York state, Dr. Pierpont asked for respondents who already believed they were suffering symptoms caused by nearby wind turbines. This self-selection bias makes it difficult to identify a causative agent. Many of the subjects suffered from pre-existing conditions including: mental health disorders, persistent migraines, continuous tinnitus and motion sensitivity, and several had a history of significant exposure to loud noise in the workplace. Similar reports, which abound in popular online literature but are absent from peer-reviewed publications, exhibit many of the same methodological flaws.[4,13]

There is some conjecture that 'sensitised' residents may have lower than normal hearing thresholds, which is theoretically possible.[25] However, such individuals are rare in the population, and, in instances where complaints about infrasound have been investigated, it is normal to find that there is little difference between the low frequency thresholds of those who complain of low-frequency noise and those who do not.[6]

One group of authors published a review in 2010 putting forward the hypothesis that certain specialised hair cells within the inner ear may respond to infrasound.[35] Within the inner ear, *inner hair cells* suspended in fluid in the cochlea transduce mechanical fluid movement (originating from vibrations of the ear drum due to sound waves) to the auditory cortex of the brain via nerve signals. These inner hair cells are responsible for almost all of the auditory capability of human hearing, i.e. sounds generally above 20 Hz, but are mostly insensitive to infrasonic frequencies. The inner ear also possesses *outer hair cells*, which are more numerous than inner hair cells, but are serviced by only a fraction of the sensory nerves that connect to the inner hair cells. Instead, outer hair cells are largely innervated by nerves carrying messages *from* the brain rather than *to* the brain. The outer hair cells respond to very loud volumes by 'dampening' the vibrations within the cochlea (this protects inner hair cells from being damaged), and by helping 'tune' the response of inner hair cells so that sounds can be better distinguished when signals reach the auditory cortex.[36] Based on animal models, the authors of the 2010 review suggested that the mechanical movement of outer hair

‡ For example, see headlines as quoted in ref.6: 'The silent sound menaces drivers', Daily Mirror, 19 October, 1969; 'Danger in unheard car sounds', Observer, 21 April, 1974; 'The silent killer all around us', London Evening News, 25 May, 1974.

cells is more sensitive to infrasound, inferring that some physiological effect can be elicited by infrasound at levels below normal auditory perception.[35] The authors propose that these effects are only likely to appear in susceptible subjects, meaning people who suffer from rare conditions affecting the inner ear. Whilst not entirely implausible, no evidence has been seen that movement of outer hair cells in this way results in signals being transmitted to the brain,[5] and it remains a speculative mechanism of action.§ Where the authors mention infrasonic frequencies measured in the noise spectrum of wind turbines, they quote values taken from distances much closer than would occur in a residential setting, giving the impression that turbine-generated infrasound is close to audible levels when in fact it would be 10 to 20 dB lower.[19,29]

Keeping with the subject of inner ear anatomy, it should be remembered that the inner ear is a poor detector of low frequency sound. It has evolved to insulate the auditory apparatus from much of the internal infrasonic frequencies produced by breathing and the pulsatile pressure waves that result from blood being pumped around the body.[19] The natural environment also contains a number of sources of infrasound, such as wind and other turbulent weather fluctuations, ocean waves and coastal wash. These are typically subaudible, although loud events such as thunderclaps or volcanic eruptions are obviously perceptible. Physical activity, like jogging or running, may temporarily generate infrasound of around 5 Hz at barely audible levels. For example, a child on a swing is subjected to a low frequency of 0.5 Hz at 110 dB.[25] In studies on normal subjects that aimed to produce ill effects from infrasound, the participants had to be subjected to very high levels of sound well within audible range, considerably higher than those produced by wind turbines.[3,21,29,37] At typical setback distances there is little difference between the audibility of natural infrasound versus that generated by wind turbines.[30,31]

Finally, it is often stated that the *weighting* of sound pressure level measurements paints a misleading picture. Because we know the human inner ear is not equally sensitive to all frequencies (see above), sound meters used in observations of environmental noise usually apply what is called *A-weighting*,[22] which accounts for the fact sounds in the mid-range of human hearing will be perceived as being louder for a given sound pressure level. However, given that the noise spectrum from wind turbines is in lower frequencies below 1,000 Hz, it has been argued that using different weightings is more appropriate to ascertain perceptible infrasound and low-

§ The authors say as much in their own paper, 'The fact that some inner ear components (such as the OHC) may respond to infrasound at the frequencies and levels generated by wind turbines does not necessarily mean that they will be perceived or disturb function in any way.' (Salt and Hullar, 2010, p.19)

Is there a case for 'wind turbine syndrome'?

To understand the refutation of the idea that infrasound causes detrimental effects to the health of residents living near wind turbines, it is useful to break down the hypothesis of 'wind turbine syndrome' into its two main parts.[7]

1. Infrasound at 1–2 Hz from wind turbines propagating through the air directly affects the vestibular system of the ear.

The vestibular apparatus within the inner ear plays an important part in balance and detecting motion, and also works in combination with the visual system to maintain focus when moving. To do this, specialised hair cells are anchored at various points within bony structures of the vestibular apparatus. These hair cells protrude into viscous fluid or gel. The inertia of these fluids are the key to detecting motion. When the rest of the head moves, the fluids lag behind and cause the hair cells to bend. This mechanical movement of the hair cells is transmitted via nerves to the brain, thereby telling the brain the nature of the movement (information about roll, pitch and yaw) and allowing compensatory muscle movements to maintain balance and keep the eyes focused on a target. This balance detection system reveals the original function of the vertebrate ear – the auditory function evolved later, giving rise to the cochlea and other structures involved with hearing, and the neural pathways are 'wired' quite differently.[36]

A recent review put forward the suggestion, based on evidence from animal models, that the mechanical movement of outer hair cells is more sensitive to infrasound, inferring that some physiological effect can be elicited by infrasound at levels below normal auditory perception.[35] The authors propose that these effects are only likely to appear in susceptible subjects, meaning people who suffer from rare conditions affecting the inner ear whose vestibular apparatus is sensitive to changes in pressure. However, no evidence has been seen that movement of outer hair cells in this way results in signals being transmitted to the brain, and it remains a speculative mechanism of action.[5] It should be remembered that within the normal, healthy inner ear the vestibular apparatus and the auditory system are well insulated from each other, the former responding to head movement and not airborne sound waves while the latter responds easily to vibrations in cochlear fluid transmitted via the ear drum.[5,19] Stimulation of the inner ear by low or infrasonic frequencies show that it is the auditory system that transmits signals to the brain.[23] Vestibular disturbances can occur when vibrations are sufficient to stimulate the hair cells of the vestibular apparatus, but this requires levels well above audible threshold, indeed, at levels that could induce trauma (120 dB), which is far above anything

frequency noise.[21,29] Two weightings that are commonly used to incorporate this low-frequency portion are *C-* and *G-weighting*. Although there are many studies available that only report A-weighted measurements from wind turbines, when C- and G-weighted measurements are given it is clear that infrasound levels are still well below audibility at distances of 100 metres or more.[5,29–31,34,38] Therefore, it is highly unlikely that exposure to infrasound from wind turbines is responsible for the myriad non-specific health issues normally attributed to it.[3,4,39,40]

Although it as advised that noise measurements taken from wind turbines should always include G-weighted levels, it appears as though the A-weighting continues to reflect human perception of the noise generated.[34] Low-frequency audible noise, i.e. not infrasound, can be a source of annoyance in certain cases (discussed in chapter 14), but it is generally concluded that 'Even close to the turbines, the infrasonic sound pressure level is much below the normal hearing threshold, and infrasound is thus not considered as a problem with turbines of the investigated size and construction [2.3–3.6 MW].'[21]

It increasingly appears that psychological expectations may explain the link between wind turbine exposure and health complaints.[4,18] From the early days of large-scale wind farm development, disruption of the visual aesthetic was typically the single most important factor governing local public support (or lack thereof) for wind turbines (see chapter 8). Increasingly, though, the perceived health effects during the planning phase have become a major concern and a strong indicator of opposition.[14] This nocebo effect may be driven largely by the way opposition groups have perpetuated the link between infrasound from wind turbines and health issues, which has been further propagated by media reports.[4,15,19]

The next section briefly discusses electromagnetic fields. More precise details of 'wind turbine syndrome' and its flaws are discussed in the box, *Is There A Case For 'Wind Turbine Syndrome'?* below.

Electromagnetic fields

The effect of negative media reporting – 'scare stories' – has also been shown to be a significant factor in other reports of non-specific health problems attributed to electromagnetic fields.[17,28] As with infrasound, there is no evidence that exposure to electromagnetic fields generated by wind turbines has an effect on nearby residents. However, there is evidence that increasing public anxiety over media reports about electromagnetic fields has led to concerns being raised at development meetings.[14,16] This seemed to come around the same time as a heightened anxiety about fears that Wi-Fi was

measured from a wind turbine.[5,21] Furthermore, where the author of the 'wind turbine syndrome' case report cited research to support the vestibular disturbance hypothesis, she failed to mention that the study in question used a vibrating device applied directly to the skull behind the ear, not air-conducted noise.[7,41] Subsequently, this misrepresentation was openly criticized in a national newspaper by the lead researcher of that selfsame study.[42] It is not surprising that the hair cells of the vestibular apparatus, being connected to the skull via the bony structure of the inner ear, will respond to vibrations applied directly to the skull, but this says nothing about how airborne infrasound can affect this system.[5,19]

2. Infrasound at the 4–8 Hz range enters the lungs via the mouth and then vibrates the diaphragm, transmitting vibration to the body's internal organs .

Proponents of 'wind turbine syndrome' posit that internal vibration conflicts with auditory and visual signals received by the brain, causing agitation, anxiety, nausea and irritability. The author coins the term 'visceral vibratory vestibular disturbance' (VVVD) to explain this phenomenon.[7]

In addition to the vestibular system mentioned above, the internal organs (generally termed the viscera) can transmit information to the brain based on the body's position and motion. This sense is called proprioception, and is initiated by the balance organs in the inner ear and by 'proprioreceptors' found in the muscles and supporting ligaments; it is also thought to involve contact and vibration receptors in the skin, although these receptors are not sensitive to sound waves at infrasound frequencies. It is the effect of infrasonic vibrations transmitted via the lungs to the diaphragm and thence to the viscera that supposedly forms the basis of VVVD.[7] The natural resonant frequency of the viscera is around 4 Hz, which is infrasonic, but the wavelength at this frequency is so long (85 metres) that the sound pressure behaves as a compression wave of negligible force, acting on the body equally from all points and thus preventing any resonant vibrations in the lungs.[37]

Air within the chest cavity does not have an effect on the resonance of the chest cavity either, so the mechanism of vibrations being conducted to the viscera seems implausible.[6] What is known is that the chest resonates at 50 to 80 Hz, but this is in response to a sound level of 80 dB; similarly, chest and abdominal resonances have been observed by exposing subjects to frequencies between 20 and 50 Hz, but this required very high sound levels exceeding 100 dB. Profoundly deaf subjects can also experience airborne infrasound, but this was a frequency of 16 Hz at 128 dB, showing that the visceral sensation of low-frequency sound requires extremely high noise levels to elicit a 'vibrotactile' response.[5,6,37]

also a possible cause of harm, for example, as found in several incredibly misguided articles concerning 'electropollution'.** The parallels between this and the scare headlines about infrasound are apparent.[4,17,43] Questions have been raised about the presence of electromagnetic fields in everyday life since the 1970s.[44] Electric and magnetic fields are close by or surround us for most of our lives in modern society, being emitted whenever a charge exists or a current flows. Evidence thus far has failed to show causal a link between adverse health effects and the exposure of individuals or populations to electromagnetic fields from appliances, residential wiring and power lines.[45]

Concerns over the potential impact of electromagnetic fields generated by wind turbines have prompted a few recent studies, which have shown that electromagnetic fields from operating wind turbines are four orders of magnitude lower than the threshold guidelines.[3]

The first study measured the electromagnetic field propagated by a large wind farm on the edge of the Black Sea in Bulgaria, consisting of 55 wind turbines rated at 3 MW each (i.e. large, utility-scale wind turbines).[46] The authors reported that the electromagnetic fields generated by the operating turbines, measured within three metres of the turbines themselves, were far below EU Council Recommendations for public exposure. The magnetic flux density recorded (magnetic flux is generated when an electric current is flowing) ranged from 0.013 to 0.023 microtesla (μT) near the wind turbines,[46] which compares with the EU recommendations that restrict public exposure to magnetic flux densities of 100 μT.[47] These levels were comparable, if not slightly lower, than levels found in the houses of the nearest village, which is to be expected given the normal magnetic fields found in residential dwellings in Europe.[44]

A more recent study of a smaller wind farm in Ontario reported similar findings to the one in Bulgaria.[16] This involved an installation of 15 wind turbines rated at 1.8 MW each – a common size, although newer turbines tend to be similar to those in the Bulgarian wind farm mentioned above. The authors of the Ontario study also took the opportunity to measure the turbines under three different conditions: when wind speed was high enough to rotate the turbines and generate power for the grid, when wind speed was insufficient to rotate the turbine but the turbine continued to draw power for general maintenance functions, and when the wind turbine and associated connector lines were shut off completely. The shut-off readings enabled the researchers to see that the background magnetic flux density was 0.03 μT. When turbines were generating for the grid or simply switched on, magnetic flux density varied between 0.09 and 0.11 μT; note, however, that these readings rapidly diminished after moving two metres away from the base of the turbine, whence they became imperceptible from the background level. Further measurements around high voltage lines and substations in the wind farm site showed that the highest reading was 1.65 μT directly below a high-voltage collector line, which diminished to the background level within 25 metres at most. Perhaps most importantly, recordings taken outside houses closest to the wind farm (500 metres) showed levels were just 0.04 μT. Any slight increase from the background level of 0.03 μT is due to the wiring normally present in residential buildings.(16) The authors note that the levels recorded were significantly lower than electromagnetic fields generated within residential buildings by common appliances, such as refrigerators and dishwashers (which generate around 4–10 μT).

Autism

In early 2010, a planning application for a wind farm was refused on the grounds that the impact on twin autistic children living nearby would be unacceptably high. The children in question had a particular obsession with spinning and turning objects, and the concern was that if they could see the turbines from their home, watching them persistently would exacerbate this already obsessive tendency††.The fact that a planning application was refused in this individual case has led to an increased discussion about autism and wind power on online forums, and this particular planning refusal seems to have become conflated with the general idea that the presence of wind turbines can both cause and exacerbate the symptoms of autism.

There is simply no evidence within the scientific literature at all that there is any causal link between the development of a new wind power installation and people nearby developing autism spectrum disorders or having the symptoms of an existing autism spectrum disorder made worse. In the absence of any peer reviewed papers on this issue, the National Autism Society, a leading advice provider for autistic people and their families were asked for a statement on this matter. NAS confirmed that this is not an issue that service users or members have raised as a concern, and that they are also not aware of any evidence suggesting a link. Their response is produced below:

> *'A low level but slowly increasing number of references are being found in anti-wind development literature to a link between autism and wind power. These reports seem originate*

** For example, see in the British Columbia Teachers' Federation magazine: L. Quiring, 'Should Wi-Fi be used in classrooms?' Teacher, v.23, No.1, September 2010, available at www.bctf.ca/publications/NewsmagArticle.aspx?id=21558.

†† http://news.bbc.co.uk/1/mobile/england/humber/8646326.stm

from the time of the refusal of planning permission in a particular case where the impacts of a wind farm development were likely to have detrimental impacts on the behaviour of twin children with autistic spectrum disorders already living nearby, and where one of the symptoms for these particular children happened to be a specific obsession with spinning objects. The concern was that for these particular children, the turbines would represent such a distraction as to make daily life very difficult for their entire family.

There is no evidence whatsoever that visibility or noise from wind turbines causes autistic spectrum disorders in previously undiagnosed individuals, or that visibility or noise from wind turbines exacerbates the symptoms of autistic spectrum disorders in most people already diagnosed with the condition.

However, as this case shows, a very specific planning issue could arise in the rare incidence that a household with an autistic family member is near to a proposed wind farm site, and where that family member's symptoms include an obsessive interest in (or particular anxiety caused by the presence of) large structures, spinning or moving objects. Such a case would be for the local planning authority to determine, in the same way that they would determine detrimental impacts of any new infrastructure on nearby residents, especially where those residents are vulnerable to change in the wider environment due to diagnosed sensory or autistic spectrum disorders. It is important to note that such considerations are an essential part of any planning application and are not limited to consideration of wind farm planning applications; such a household could be equally negatively impacted by the construction of a new road, or pedestrian crossing that adds new lights and sounds into the local environment.

The fact that an individual planning application has been refused on the grounds that a local resident with autism could have been severely affected by the introduction of wind turbines into their local environment in no way suggests *that the presence of wind turbines can trigger autism in otherwise unaffected individuals or routinely exacerbates the symptoms for individuals with previously diagnosed autistic spectrum disorders.'*

Pers. Comm., Head of Centre, National Autistic Society, 22/02/16

Conclusion

The hypothesis that operating wind turbines are responsible for a number of non-specific health issues, collectively grouped as 'wind turbine syndrome' lacks both plausibility and evidence, as does the suggestion that wind power can cause or exacerbate autism. In the 2000s, objection to wind turbines on the basis that low-frequency noise or infrasound was hazardous to health prompted several observational studies on the nature of sound generated by wind turbines. Whilst it is certainly the case that the noise spectrum of wind turbines has a proportionally large low-frequency and infrasonic component, measurements of environmental exposure due to operating wind farms have repeatedly failed to show that infrasound can have a demonstrable physiological effect on nearby residents.[3,5,21,29] Adverse effects on humans are only evident at infrasound levels far exceeding that generated by operating wind turbines.[5,6] The UK Health Protection Agency welcomed additional research in the field of environmental infrasound in a 2010 report, whilst acknowledging the lack of evidence supporting wind turbine-generated infrasound as a health risk.[37] Studies published since then have continued to show that infrasound from wind turbines is at levels below audibility and within guidelines.[48] The recognition that the noise spectrum of wind turbines warrants investigation using different weightings more suited to low-frequency noise has been taken on board in more recent studies, but the evidence still shows the same results, and it is highly likely that the more conventional weighting (A-weighting) remains an adequate reflection of human perception of noise.[34,48] Indeed, in many cases, G-weighted measurements suggest wind turbine infrasound is less than the infra-sound produced by naturally occurring phenomena.[25,30,31]

Similar to infrasound, another concern that has appeared with greater regularity in the last decade is the fear that wind turbines generate electromagnetic fields. This is raised as another objection on the grounds that it poses a risk to residents' health.[3,14,16] Measurements of electromagnetic fields generated by wind turbines suggest the strength of these fields are comparable to background levels, becoming imperceptible when moving just a few metres away from the turbine.[16,46] The history of health scares relating to electromagnetic fields echoes to a large extent similar headlines about the 'silent menace' of infrasound. The rise in the number of complaints about 'electrosensitivity' since the 1970s has failed to demonstrate any link between exposure to electromagnetic fields and symptoms.[28] What is clear is that people's perceived exposure is a consistent predictor of non-specific health conditions being reported.[49–51] Increased reporting of 'scare stories' that attribute a variety of non-specific health problems to the technological trappings of modern society set up an expectation in the minds of many, increasing their

anxiety and subsequently manifesting as broad symptoms, including ear symptoms, headache, fatigue, dizziness and sleep problems, that may become quite debilitating for some of those affected.[6,17,28,43] There is evidence that suggests this nocebo effect is behind the increase in self-reported symptoms attributed to nearby wind farms.[4,15,18] This seems plausible in light of similar findings regarding electromagnetic fields and negative expectations, and may shed some light on why exposure to objectively measured noise from wind turbines does not match up with subjectively reported symptoms.[3,6,40]

Why is the propagation of the 'wind turbine syndrome' myth and the perception of harm to health from wind power so important? To be absolutely clear, although infrasound is demonstrably not causing harm, there is much stronger evidence that audible sound from wind turbines can be a source of annoyance and have a negative impact on quality of life for a small number of nearby residents.[52,53] This is discussed in detail in chapter 14. Creating conditions such as 'wind turbine syndrome', despite the lack of any corroborating evidence, is a confusing and unnecessary addition to the real and complex problem of noise disturbance.[19] The widespread dissemination of these and similar 'health scares' through avenues for public discourse – particularly the internet – has led to an alarming amount of unsubstantiated reporting among groups with a vested interest in opposing wind farm developments, which further increases the potential for these reports to trigger anxiety among sections of the population.[17,43]

Reinforcing the belief that wind turbines are the cause of underlying health issues confounds the treatment of sufferers, because they are fixated on an external agency as the cause of their distress, despite the lack of evidence for a direct pathophysiological relationship between infrasound and their symptoms.[19,27,54] This has important implications, given the power that negative expectations have on how wind turbine noise is perceived by residents.[18,43,54,55] There is an important and powerful social dimension to the interaction between wind power and communities, and the undue influence that myths such as 'wind turbine syndrome' continues to exert only serves as an unnecessary and harmful distraction from the real issues that planners and communities should address.

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