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Compliance isn't everything.

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Summary

Wind farm noise complaints are prevalent in the UK. Few cases make headlines and those that do are typically larger wind turbine or offshore developments. In the last few years complaints from smaller wind turbines (rated power in the region of 50kW or less) have increased. Complaints typically focus on the character of the noise rather than the decibel level or volume.

At the planning stage (in the UK) applications that are shown to meet a simplified noise limit of 35dB LA90 up to wind speeds of 10m/s are commonly approved without question of adverse noise impact. It is widely assumed that noise levels below this threshold will not cause disturbance and turbine manufacturer's information on noise can also often be misleading.

This paper examines noise impact from smaller wind turbines which, due to their size and the number of people potentially affected, are often neglected. Case studies are provided that follow turbines approved at planning that have been erected, tested and found to comply with noise limits but which have caused or continue to cause noise complaints. It investigates the character of noise generated by smaller wind turbines and questions whether the methodology currently used is providing adequate protection to wind turbine neighbours.

1.0 Introduction

In the UK guidance for assessing noise impact from wind turbines, ETSU-R-97, sets a lower threshold limit of 35dB LA90. If turbines can be shown to meet this limit then there is arguably no reason to refuse planning permission on noise grounds. This guidance is reinforced by a 'good practice guide' published by the UK's Institute of Acoustics, which supports use of the 35dB LA90 limit to turbines with a rated power above 50kW. At the time that ETSU-R-97 was published it assessed turbines with rated power typically in the region of 225-400kW. Nowadays it is more commonly applied to turbines with a rated power in the region of 2-3MW. The ETSU-R-97 noise limit permits higher levels of noise from wind turbines than other types of industrial development. This is justified as balance between some adverse impact caused to wind farm neighbours and the need for renewable energy. Applying noise limits originally designed for turbines with rated power in excess of 225kW and now more commonly applied to turbines rated 2-3MW to

turbines rated 50kW, or sometimes less, shifts the planning balance. Development is permitted with the same level of adverse noise impact as for larger turbines but with far less renewable energy return.

The application of ETSU-R-97, guidance for larger wind turbines, to wind turbines with a lower rated power creates a further problem that arises from the difference in noise character between smaller and larger wind turbines. The noise limits prescribed in ETSU-R-97 do not include any adjustment for noise character, with the exception of a maximum 5dB tonal penalty. In contrast with larger wind turbines, noise from smaller wind turbines can be much more easily influenced by wind conditions and as such noise impact can be highly changeable. As shown with the examples below, smaller machines often have more distinctive noise character, both in terms of how the character manifests, for example blade 'swish' or tonality, and in terms of the regularity and predictability of the noise.

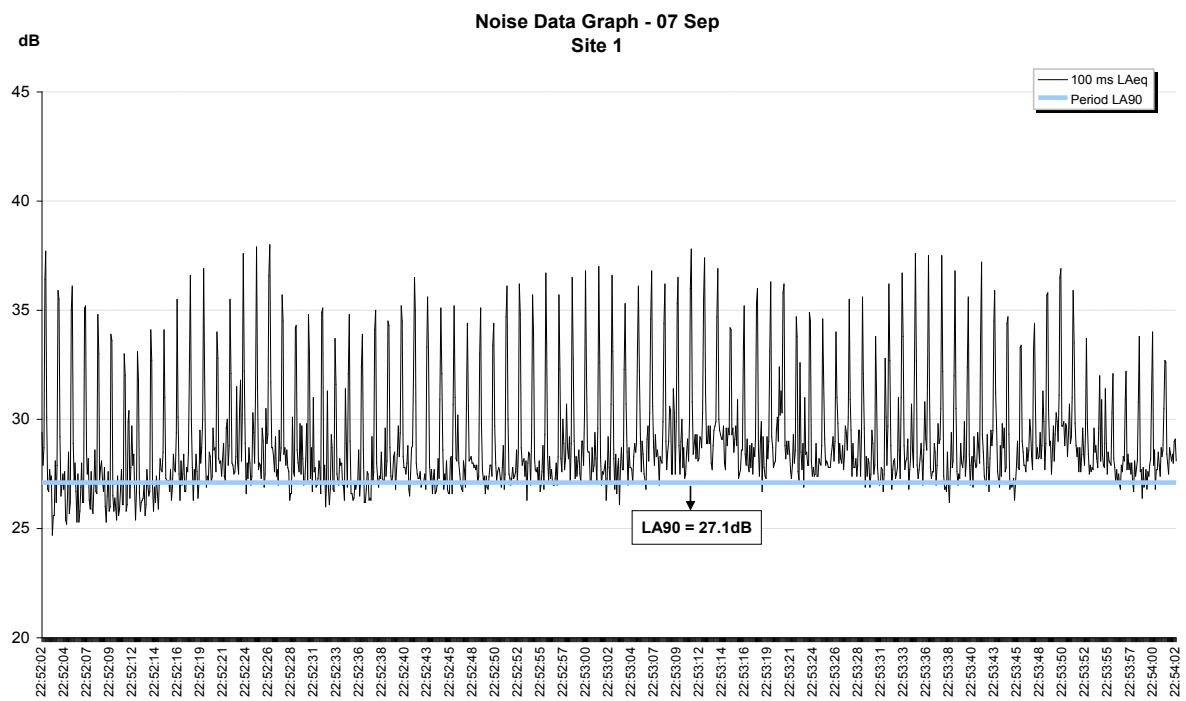
2.0 Wind turbine noise field measurements

The measurements below are taken from three different sites in the UK where residents have complained of noise from the same model of 50kW wind turbine. The wind turbine noise is characterised by strong tonality, though this presents in a different way in each case. All measurements were taken external to the dwelling, though noise impact in each case was also reported as audible and disturbing within the dwelling. Measurements were taken using type 1 sound level meters. The 100ms LAeq was recorded along with 100ms 1/3rd octave band spectral data, period LAeq, period LA90 and high quality audio.

2.1 Site 1

This site is located in the east of England. The complainants were located approximately 430m from the wind turbine and complained of the character of the noise, saying that it was difficult to ignore. Figure 1 below gives a two minute period of noise measured at the dwelling and which is entirely dominated by wind turbine noise.

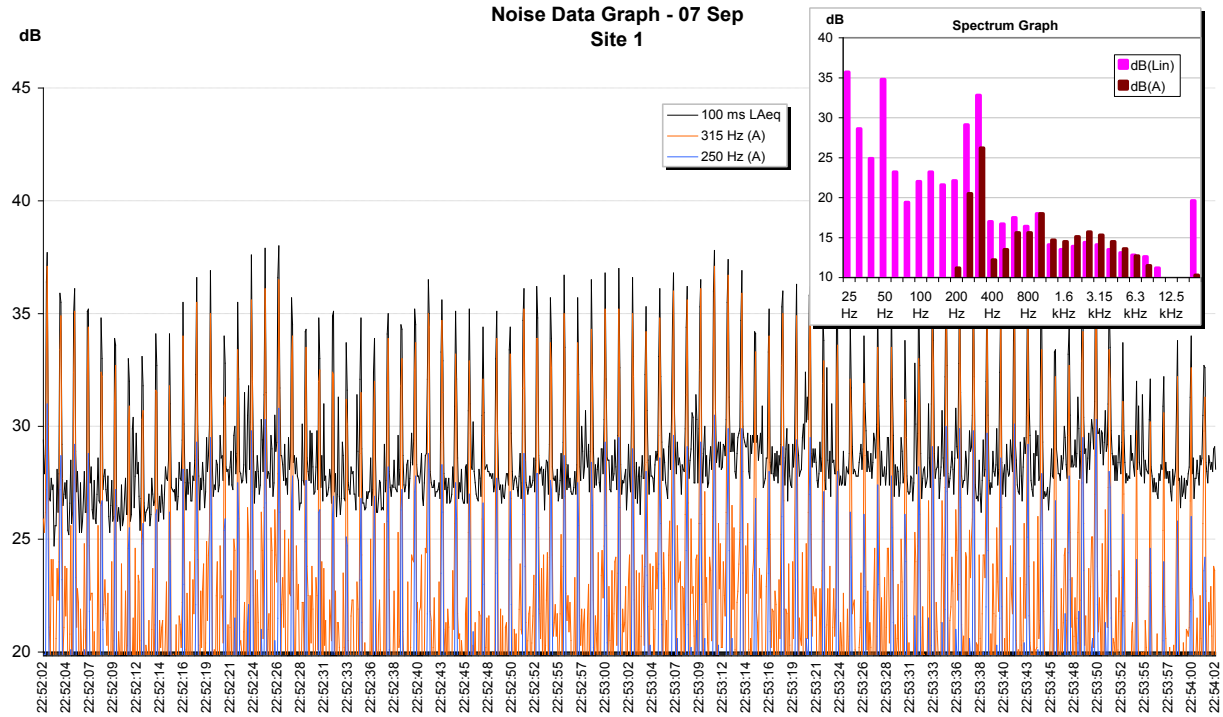
Figure 1: Site 1: 22:52



The noise from the turbine is highly tonal and rhythmic. In this case the noise is fairly regular and predictable; however, the quasi-musical nature of the noise makes it difficult to ignore or become accustomed to and increases the annoying quality of the noise,. The LA90 for the 10 minute period from which the extract is taken is indicated by the blue horizontal line at 27.1dB(A).

Figure 2 below shows the same period as figure 1 but with the 100ms trace of the two third octave bands, 250Hz and 315Hz, that dominate the overall A-weighted 100ms trace also plotted on the graph. The noise in these third octave bands is attributable to the turbine. A comparison of the third octave bands and the overall A weighted noise level confirms that the turbine noise is dominating the noise environment during this period. Also inset in figure 2 is a spectral graph of the two minute period. This gives a good indication of the strong tonality of the turbine noise. Analysis of the audio data confirms that the tone is at approximately 280Hz. Some tonality is also audible at a higher frequency of around 1kHz. The higher frequency is a more consistent whine compared to the mid frequency pulsating hum and is far less dominant within the overall noise level than the hum.

Figure 2: Site 1 - 22:52 with spectral data



2.2 Site 2.

This site is also in the east of England. The nearest residents are located approximately 470m from the turbine, but a number of residents in the community have complained of the noise. The noise is audible and disturbing both inside and outside of the dwelling. The complaints have focussed on the mechanical droning and whirring character of the noise. This description is clearly supported by the tonality and rhythmic quality of the noise data. Figure 3 (below) is a 1 minute extract during which turbine noise is dominant. Some noise from livestock is audible throughout the period and provides useful context to the turbine noise within a rural setting.

Also plotted on the graph are the 315Hz and 1kHz third octave band 100ms traces. This corresponds to the tonal character of the turbine, which as with site 1 has a higher frequency whine and a mid frequency hum. In contrast to site 1 the higher

frequency whine and the mid frequency hum are both fairly equally dominant within this noise trace. The third octave band traces, plotted on figure 3, show how the dominance of the tonality changes with time. Also plotted on the graph is the 10 minute period LA90.

Figure 3: Site 2 – 23:06

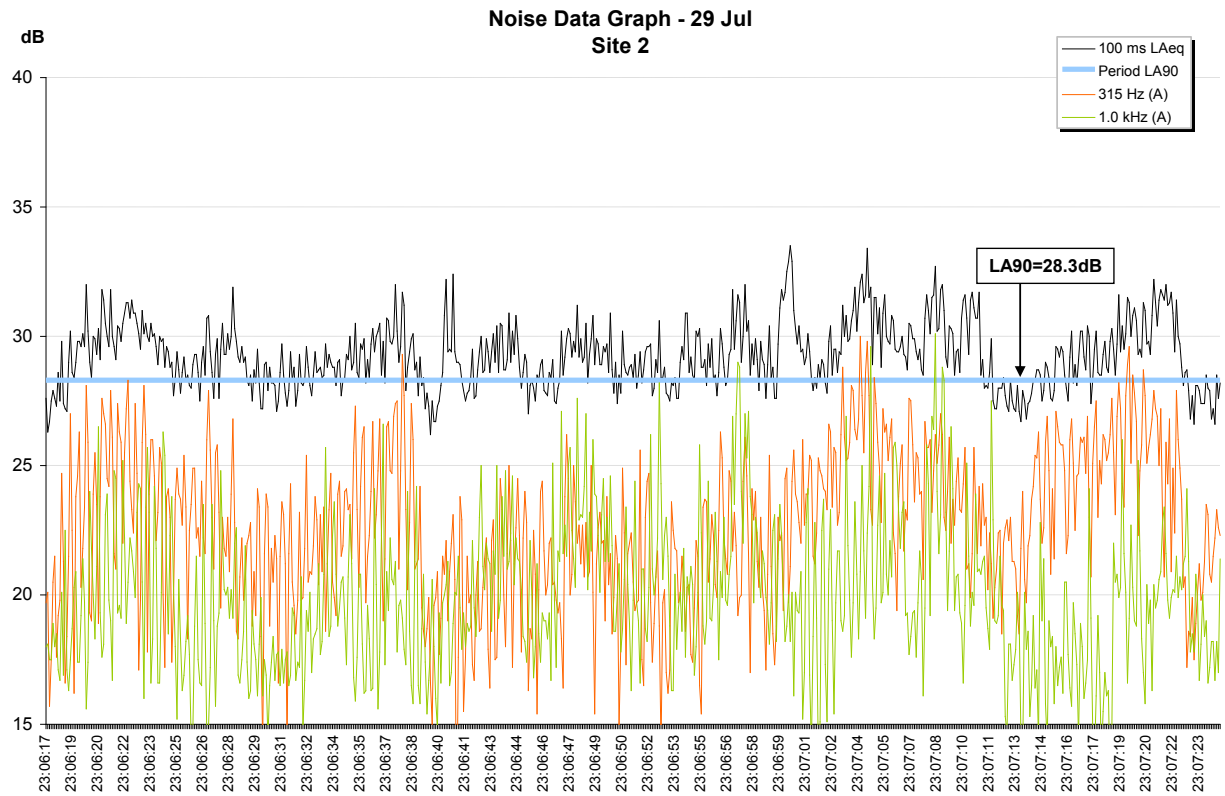
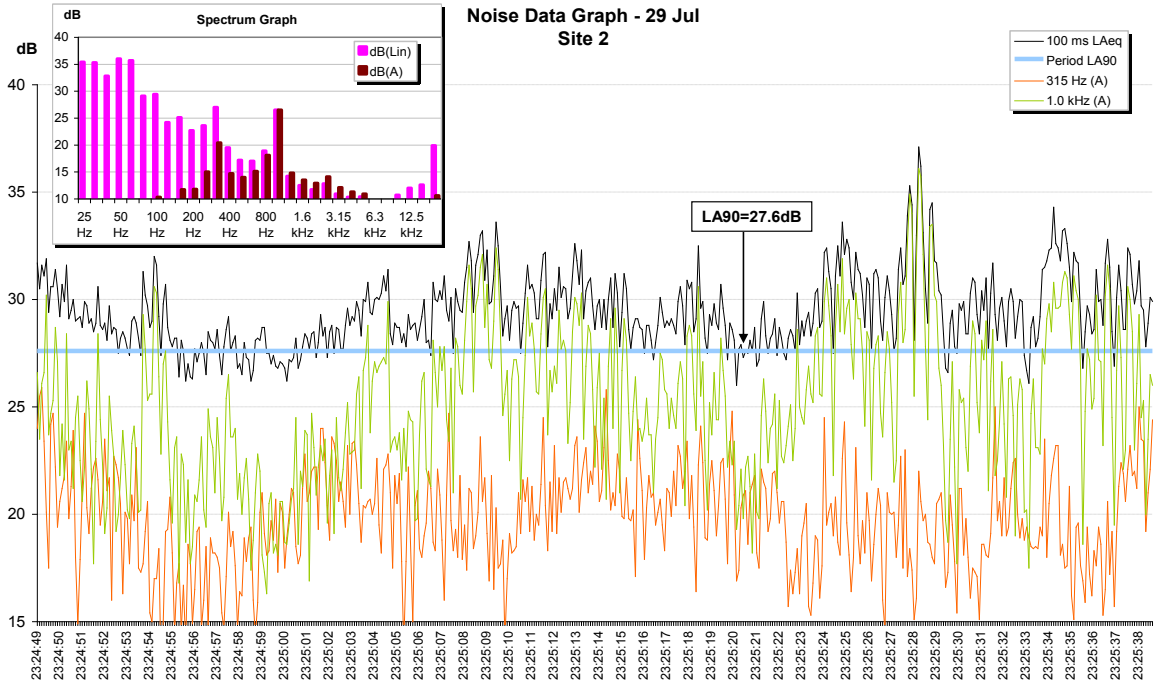


Figure 4 (below) shows another extract of turbine noise from site 2. During this extract the higher frequency whine at around 1kHz becomes particularly prevalent and manifests for short periods as a 'resonant' type noise.[1] 'Resonances' can be identified on the graph below as periods where the green 1kHz third octave band trace meets the overall A weighted noise trace. Also plotted on the graph is the spectral data for the period and the 10 minute period LA90.

[1] Tonal resonance refers to a rise in identifiable tonal content, an increase in energy at a specific frequency.

Figure 4: Site 2 – 23:24



2.3 Site 3

This turbine is located in the West Midlands. Residents are located approximately 350m from the turbine. A number of residents have complained of the noise, particularly the constant whine / hum from the machine which, reportedly, can be intrusive in a range of wind directions. Figure 5 below shows a period dominated by turbine noise. Also plotted on the graph is the 10 minute period LA90.

Figure 5: Site 3 – 00:57

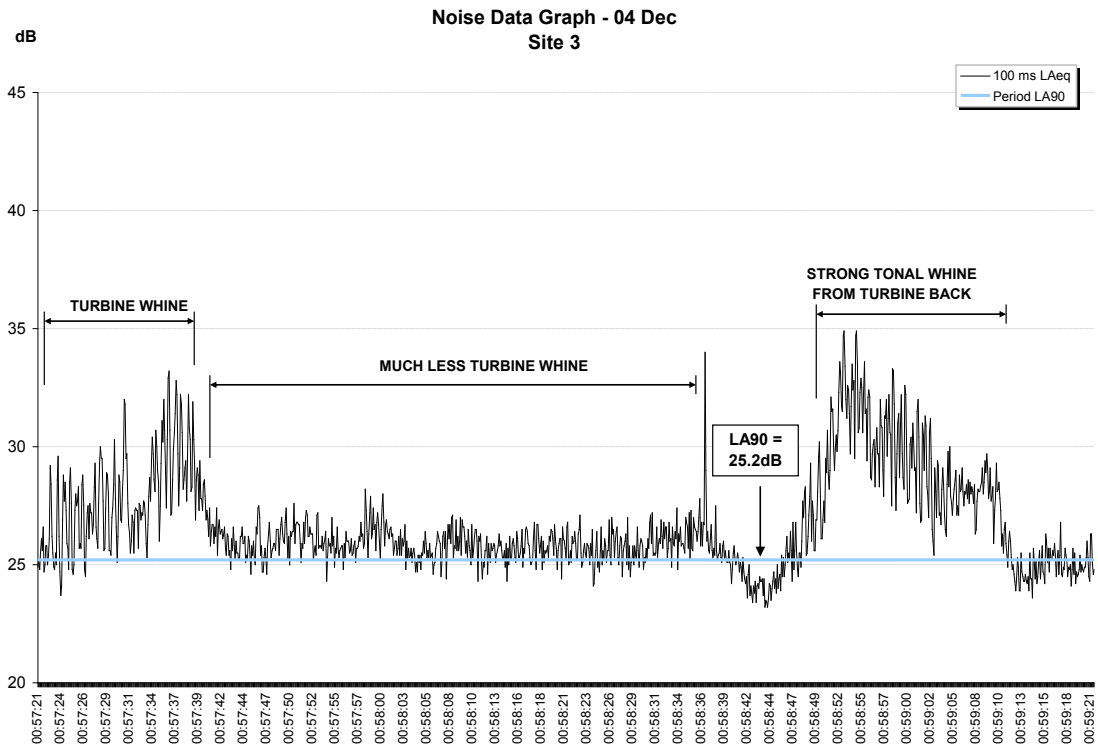


Figure 6 below shows the same period above but with the 1kHz third octave band trace plotted on the graph and also the spectral content of the period plotted on the inset graph. Figure 6 confirms the tonality of the whine at 1kHz and demonstrates how the dominance of the tonal noise within the overall A weighted noise trace can vary significantly over a short time period.

Figure 6: Site 3 – 00:57 including spectral content

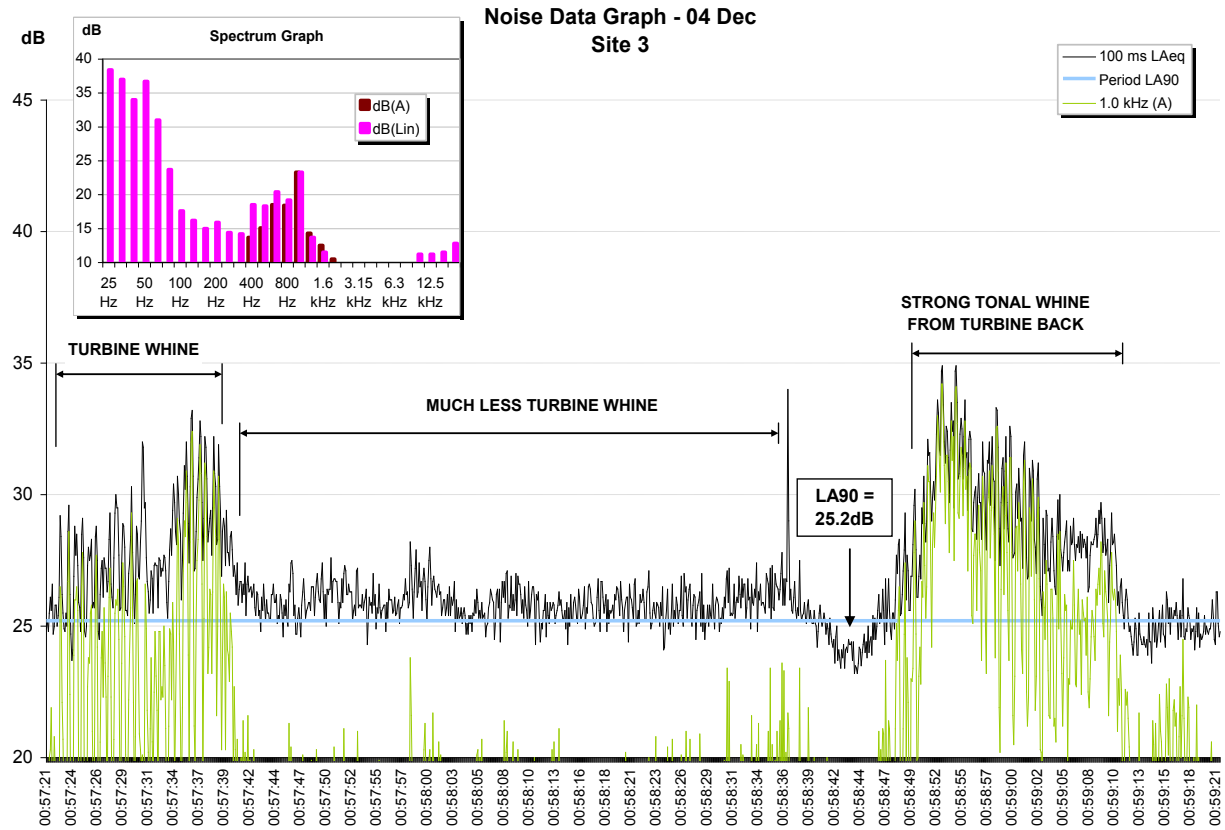


Figure 7 below shows a period from earlier in the evening when the turbine noise is dominant, though variable in decibel level and tonal dominance. Also plotted on the graph is the 250Hz third octave band trace. This represents the lower hum of the turbine which is not as prevalent at this site but can just be heard, in and out of audibility, in some parts of this extract.

Figure 7: Site 3 – 00:23

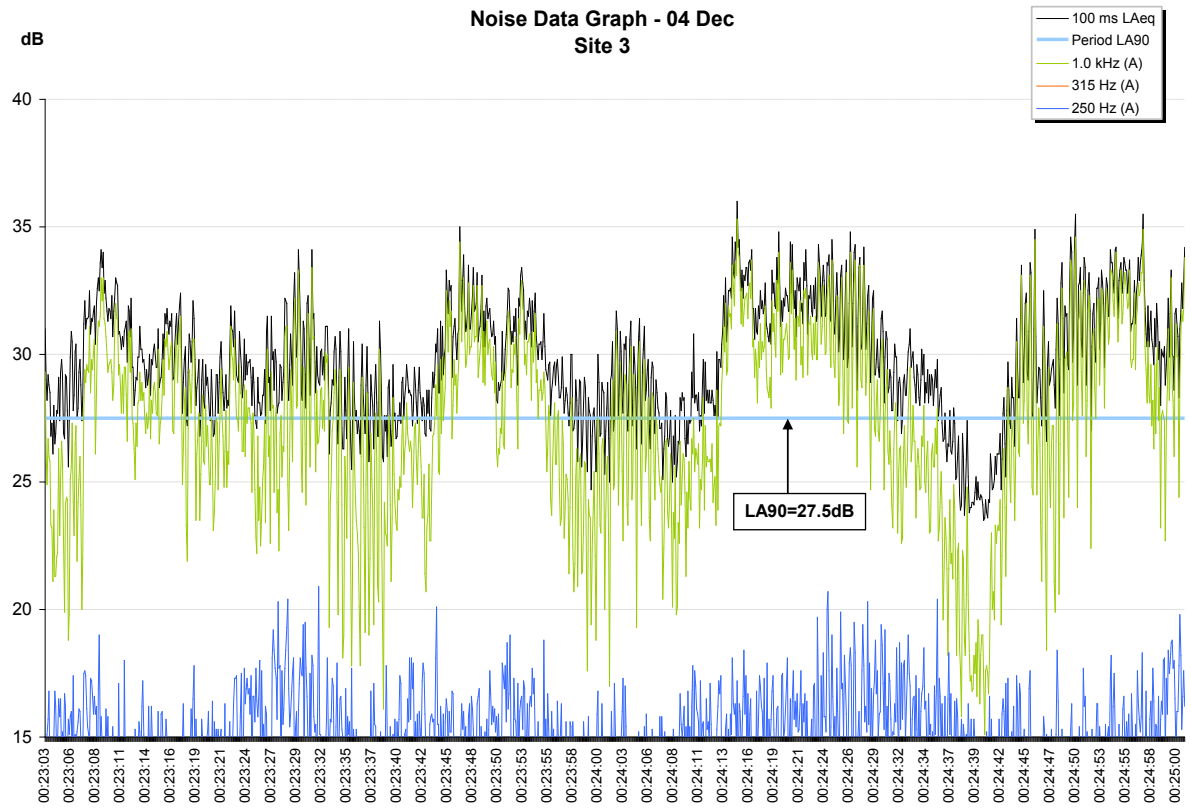
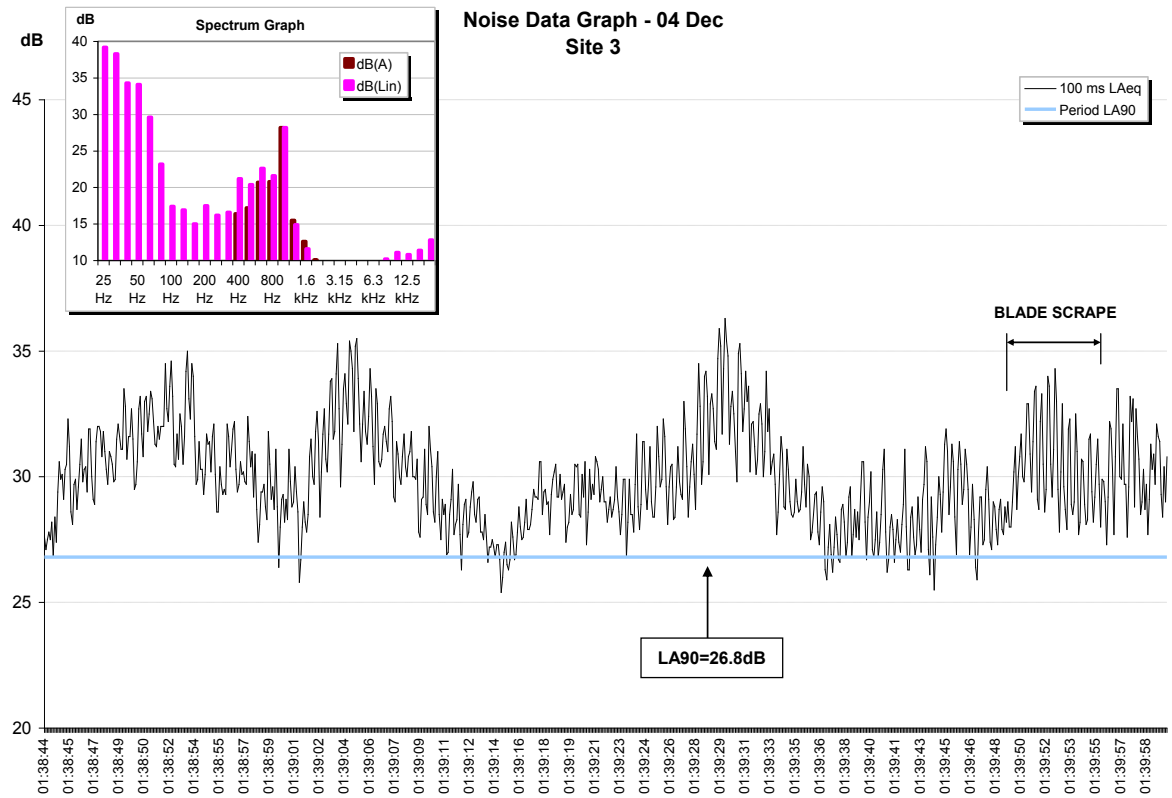


Figure 8 below shows another period where turbine noise, and particularly tonal turbine noise, is dominant. At the end of the period blade noise, a scraping sound, is clearly audible in the data.

Figure 8: Site 3 – 01:38



3.0 Assessment of character

The above graphs give examples from three sites all with single 50kW wind turbines that generate a dominant and tonal noise source in otherwise rural environments. All turbines have caused complaints, at two sites there are multiple complainants. Whilst all sites have an overarching tonal character in common, each manifests differently. At site 1 the noise is dominant in the mid frequencies as a pulsating hum (315Hz). The tonal noise is very rhythmic and whilst there is a higher frequency whine this is far less intrusive. Both the higher frequency whine and the mid frequency hum are present at site 2. The site 2 turbine also frequently causes a 'resonant' type noise, where the higher frequency whine becomes much stronger and the character changes from a pulsating tone to a constant tone, for a short period and temporarily. At site 3 the higher frequency whine is clearly dominant and only on a couple of occasions is the mid frequency hum discernible in the audio data. Noise from the turbine blades is also more prevalent at site 3. The blades generate a scraping type sound that is not always present. This contrasts with the highly tonal whine of the turbine which although variable in loudness is typically always audible in the data.

The table below provides a summary of the turbine noise at each site. The table provides an indication of tonality by comparing adjacent third octave bands. It then compares the LA90 of the turbine noise, as would be measured to test compliance, with the simplified noise limit of ETSU-R-97 to give an indication of nominal 'acceptability'. This includes an assumption that the maximum 5dB tonal penalty would be applied to the turbine noise.

Table 1: Summary of turbine noise levels at sites 1, 2 and 3

Site / time	Measured LA90,10min	Difference between adjacent 1/3rd octave bands[2]	Compliant?.
Site 1 22:52	27.1	*7dB / 16dB*[3]	Yes, by 3dB (35-27.1+5)
Site 2 23:06	28.3	0.5dB / 7dB *3dB / 11dB*[4]	Yes by 2dB
Site 2 23:24	27.6	8dB / 12dB	Yes by 2dB
Site 3 00:57	25.2	5dB / 9dB	Yes by 5dB
Site 3 00:23	27.5	8dB / 14dB	Yes by 2.5dB
Site 3 01:38	26.8	7dB / 13dB	Yes by 3dB

[2] This indicates the difference between the 1kHz third octave band and the 800Hz third octave band followed by the difference between the 1kHz third octave band and the 1.25kHz third octave band unless otherwise specified. The calculation is based on linear third octave band levels.

[3] This is the difference between the 250Hz third octave band and the 200Hz third octave band followed by the difference between the 315Hz third octave band and the 400Hz third octave band. The tonal hum straddles the 250Hz and 315Hz third octave bands and hence is reflected in both third octave bands.

[4] This is the difference between the 315Hz third octave band and the 250Hz third octave band and the 315Hz third octave band and the 400Hz third octave band.

A simple aural analysis of the audio data confirms that subjectively the turbine noise character is highly tonal. This is supported by the comparison of third octave band data. Typically a difference of 8dB in the mid frequency third octave bands (160Hz – 400Hz) and a difference of 5dB in the high frequency third octave bands (500Hz – 10,000 Hz) indicates tonality. The table above confirms that at sites 1, 2 and 3 even with a maximum 5dB tonal penalty the turbine noise complies with a lower noise limit of 35dB LA90 by a minimum of 2dB.

4.0 Discussion

The examples from sites 1, 2 and 3 and the analysis in the table above provide clear evidence that use of ETSU-R-97 limits inclusive of a tonal penalty does not provide sufficient protection for the local community. It is easy to demonstrate compliance with single examples, typically months of data is used to assess compliance. This allows periods of complaints to be averaged with periods that may not have generated complaints. The averaging process reduces the likelihood that a breach will arise. Thus, although the above table indicates compliance by a minimum margin of 2dB, this is likely to increase as more data is gathered and averaged. Compliance does not prevent complaints.

It is often argued that noise levels below 35dB(A) (Leq or L90) are so low as to be incapable of causing adverse impact. It is often argued that a minority of people will always complain and this argument is used successfully to undermine complaints that are indicative of unreasonable noise impact.

4.1 Does noise have to be loud to be intrusive?

Anecdotally it is clear that sound does not need to be loud to be intrusive. Sound at a low level can cause extreme annoyance; a dripping tap or buzzing mosquito are two common examples. Colloquial commentary highlights the importance of context. It placing perspective of the absolute noise level on the situation and character of the area in which the noise occurs. Amorosano (2014) discusses eight sounds that are only annoying in the quiet section (of the library). She lists music though headphones, uncontrollable bodily functions (coughing, sniffing etc), eating (e.g. a packet of crisps), typing, writing (freshly sharpened pencil on paper), breathing and silence. Like turbine noise, these sounds may not be considered 'loud' but in context with very quiet background noise levels they become increasingly annoying and disturbing.

It is widely accepted that a range of factors contribute to noise annoyance. They include:

- → Tonality – noise with discrete tones even if at a lower decibel level are more annoying than broad band noise.
- → Changes in noise level – changes in noise level will draw attention to the sound and are more difficult to acclimatise to than a noise with a steady non fluctuating decibel level.
- → Time of occurrence – noise that occurs at noise sensitive hours, for example at night time, is generally considered more annoying than noise that occurs during the daytime. Barron (2003, p.284) found that noise that occurred during night time was 10dB more annoying than noise occurring during daytime hours only.
- → Frequency (pitch) – at equal levels, high frequency sound is more annoying than low frequency sound.
- → Duration – sounds that last for longer are typically more annoying.

→ Irregularity – sounds that are impulsive or irregular (unpredictable) are more annoying than regular predictable sounds.

The courts in the UK have ruled that noise need not be measurable to be considered a nuisance, see Godfrey v Conwy County Borough Council [2001] Env.L.R 38. It follows that if the noise cannot be measured, i.e. separated from the ambient noise, it is not very 'loud' at least in comparison to other noise sources in the environment. However, by nature of its character the noise is obtrusive. Noise that has particular character does not therefore need to be 'loud' to be unreasonable.

It becomes apparent when discussing noise issues with complainants that noise level is only one factor that contributes to noise annoyance; this is further supported by research (Pedersen, 2007). As noted in Cohen and Spacapan (1984):

> *Although social surveys often report a positive relationship between noise intensity and the average level of felt annoyance, intensity alone seldom explains more than one-quarter of the variance in individual annoyance reactions (cf. McKennel, 1973).*

The World Health Organisation (WHO) Guidelines for Community Noise (1999) are widely referenced in literature and provide threshold levels below which certain adverse affects of noise are not widely observed. It is noted that these guidelines are concerned primarily with transportation noise and within the guidelines there is a heavy caveat against the application of these guideline values to noise with specific character. As noted by Flindell and Walker (2004), approaches that apply threshold levels assume that the dose response relationship upon which they are based is accurate. Amplified music noise is used as an example of an annoying sound that occurs at relatively low sound levels but which causes annoyance. Music noise has parallels with wind turbine noise: both occur at relatively low levels, have particular noise character (tonality, amplitude modulation, rhythmic features) and typically disturb at night time when background noise levels are low.

Flindell and Walker (2004, p.214) note that even where music noise is only just audible considerable annoyance can be caused and that:

> *Practical experience suggests that some individuals can become increasingly sensitised to this type of auditory stimulus, so that even where they might at first have been able to ignore noise intruding at several decibels above the masked threshold level, they may, in time, find that they are becoming increasingly disturbed by any identifiable music noise which is only just audible.*

Whilst studies have found that wind farm noise is more annoying at lower levels of noise than other industrial noise sources (Pedersen, 2009), this seems to be further exacerbated by the particular character and manifestation of turbine noise, particularly in smaller turbines. The noise at sites 1, 2 and 3 all contain features listed above as contributing to considerable annoyance. The turbine noise is tonal and contains higher frequency noise (the tonality at 1kHz coincides with the most sensitive range of human hearing). The turbine noise fluctuates in decibel level and loudness, it occurs at night time and when there are very low background noise levels, it is irregular and in most cases unpredictable and can continue for long periods of sustained impact. Compliance, as assessed above, considers only two of the many relevant factors contributing to annoyance: decibel level and tonality. The examples at sites 1, 2 and 3 patently

demonstrate that simple application of a tonal penalty to the overall noise limit fails to enforce unreasonable impact. Compliance testing falls short both in assessing and enforcing targeted characteristics (tonality, decibel level) and neglects other character features that also contribute to and exacerbate annoyance.

4.2 Complaints

Residents affected by sites 1, 2 and 3 have all complained to their local authority. Little has been done to resolve or reduce impact, "people will always complain". Whilst complaints are often used to indicate the extent of a noise problem, evidence suggests that many will not complain and that in reality the mere presence of complaints is indicative of a much wider problem.

A report commissioned by Health Protection Agency (HPA) found that "for all noise sources the most common response is to take no action" (2010, p.34). The report notes that not everyone adversely affected by noise complains and that those affected are unlikely to complain to the noise polluter let alone make an official complaint to an authority (HPA, 2010, p.43). Miller (1971) states that "only a small percentage of those who are highly annoyed or disturbed actually register a formal complaint" and cites an equation devised by Tracor Staff (1971) that relates to 600 highly annoyed households in a community of 1000 households where 200 have complained. World Health Organisation (WHO) guidance to local authorities 'Noise and Health' advises that:

> *15-25% of people identified as 'highly annoyed' by noise in social surveys are estimated to complain… the number of inhabitants in a community exposed to noise affects the number of complaints – and probably the importance attached to them by local authorities.* (2000, p.a12).

The WHO (2000) guidance identifies an important aspect of complaints and community response. Where a local authority attributes little importance to a complaint it is unlikely that a resident will persevere and pursue resolution. Learned helplessness and demoralisation, the notion that nothing beneficial will result from any complaint, is a further issue that influences complaint statistics. The CIEH Survey of Local Authority Noise Enforcement Activity (2013) found that only approximately 6% of all noise complaints resulted in any action, either serving a notice, commencement of prosecution or some other remedy. Only 46% of local authorities responded to the survey.

Contrary to the assertion that people always complain, evidence suggests that it is rare for those affected to complain to the polluter or the local authority. A further and very serious issue in the UK is the requirement for property owners to declare any formal noise complaints on selling their property. This has clear consequences for the final selling price and it is understandable that once made aware of the prospect of falling house prices in an already turbulent market, potential complainants might be otherwise diverted. Where complaints do arise, evidence suggests that a wider problem exists.

5.0 Conclusions

Noise measurements from three separate UK sites, each with the same model of single 50kW turbine, found turbine noise with specific intrusive noise characteristics. In each case the turbine noise has triggered complaints from local residents. Comparison against UK guidance ETSU-R-97 and the lowest attributable noise limit of 35dB LA90 found that in each case turbine noise was compliant with the limit by a minimum margin of 2dB. This included a maximum attributable 5dB penalty for tonality. Noise character is

a problem particularly with smaller wind turbines as illustrated by the examples at sites 1, 2 and 3. The presence of noise character increases annoyance. Compliance testing in its current form fails to prevent complaints or adverse impact and significantly overlooks other character features that contribute to the onset of complaints. The findings from site 1, 2 and 3 suggest that a revised approach to assessing noise impact, at least for smaller wind turbines, is needed. Threshold limits with decibel penalties fail to work in their current form. That complaints arise from this type and size of turbine and continue to arise in different locations suggests that a much wider problem exists. In the face of compliance residents have little recompense for interference with the right to respect for private and family life.

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