Sensing but Not Hearing: The Problem of Wind Turbine Noise (Interview with acoustician Steven Cooper, AU)

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Editor Note: **Steven Cooper has advanced our understanding of how people react to real recorded pressure pulsations from industrial wind turbines. In the last six months he has presented eight papers at Acoustic Meetings in Zurich, Boston and New Orleans. With this interview, he breaks down some of the salient points of his research discoveries. Cooper's work is expanding our knowledge about "soundscapes" near projects, which could result in new legal requirements for manufacturers and developers.**

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>
> – Stephen Cooper (below)

Q. Paul Gipe back in his 1995 treatise (*Wind Power Comes of Age*, pp. 371-73): stated, "Next to aesthetic impact, no aspect of wind energy creates more alarm or more debate than noise." He explained in his book how "all wind turbines create unwanted sound" and that sound can carry for great distances. Given this, why, twenty years later, is noise pollution and health effects therein just entering the mainstream?

Cooper:

First, some background. Sound is all around us unless we are in a vacuum. Noise is defined as unwanted sound and has been used as a descriptor by acousticians and authorities for more than 50 years.

'Noise pollution' could be taken as the concept of considering noise overall as being evident and affecting people to various extents with the concept of noise pollution being expressed in the late 1980s possibly more as a side issue to the common concept of air pollution.

Excessive noise or sound that may impact upon a person's health has been well-known for 60-plus years via occupational noise with relevant standards being issued for noise levels in a workplace environment.

With new investigation, the noise criteria applicable to occupational noise has been modified for general factory-type noise and then expanded for different type noises that do not accord with general everyday noise and result in different impacts on people's hearing, i.e. impulsive noise associated with hammering of steel, explosions, or firing of rifles.

In relation to general noise pollution (in terms of mainstream noise), the issue of health effects associated with road traffic noise, rail-traffic noise and aircraft noise entered mainstream issues before the 1995 extract that you have quoted. The general concept in terms of ascertaining appropriate **noise limits** for those types of noise involve community surveys and socio-acoustic studies to derive a dose-response curve where a noise limit was set to ensure that 90% of the population was not subject to an excessive degree of noise (with respect to annoyance) for 90% of the time.

With respect to wind turbine noise, in the mid-1990s the provision of wind turbines in rural communities came to the fore with respect to unwanted noise. Clearly the noise generated by such turbines was totally different to that of the existing environment. Whilst persons in proximity to wind turbines identified annoyance and sleep disturbance in mainstream acoustics, the number of people so affected is a small proportion of the total population and therefore did not warrant socio-acoustic studies.

If in the general sense the impact of turbines is limited to a small area around a wind farm (when compared with the total area of a regional county or the state) then the environmental authorities do not consider it to be a significant issue warranting further investigation.

Material conducted in relation to community response to wind turbines in Sweden and the Netherlands identified a dose-response curve significantly lower than that for road, rail or aircraft noise and suggested the appropriate limits for wind turbine should be significantly lower. However, that work related to relatively small turbines and an increase in the capacity of turbines to those which exist today results in a greater level of noise emitted from turbines.

Environmental authorities, encouraged by the wind industry, utilize noise criteria for turbines based upon road-traffic noise, notwithstanding the two noises are not the same.

The WHO 2009 European night-time noise guidelines identifies that ongoing noise disturbance, particularly with respect to sleep disturbance can lead to health impacts. It is necessary to note that most of the noise data contained in the 2009 guidelines relates to road traffic noise in urban areas. There is no data contained in the study related to wind turbines.

The various WHO guidelines that have been published identify where a noise contains a dominant low-frequency component then a further penalty should be added to any assessment criteria. Similarly, if a noise contains an impulsive characteristic then a further penalty should apply.

In general, wind farm applications claim that turbines do not generate any low-frequency, tonal, or impulsive characteristics, which is a matter disputed by residential receivers.

The consequence of the pulsating signal generated by turbines (whether audible or inaudible) could potentially require a further adjustment to any perception or impact generated by wind turbines.

In general, the noise criteria specified for wind turbine facilities is related to external noise levels, not internal noise levels. The spectrum of wind turbine noise can often be masked by external noise sources at an external location. But when assessed inside the dwelling, the reduction in sound provided by the building envelope dramatically reduces the high frequency components of both the external noise and the wind turbine noise, leading to a totally different spectral balance of the sound inside the dwelling that can make the audible characteristics of such turbines more apparent.

Q. How long have you been researching noise, vibration, sound, ILFN (Infra and Low Frequency Noise), and now, pressure pulsations, from industrial wind? How did you become interested in this?

A. I have been an acoustic engineer for 39 years and had a basic grounding in large scale industrial plants then helicopter and aircraft noise. I am involved in development applications for different types of projects and provided expert evidence on acoustic matters, primarily before planning courts.

In 2012, I was asked to review a proposed wind farm application and found a lack of evidence for the basis of the acoustic criteria that was proposed. The level of disturbance reported by residents in proximity to existing wind farms contradicted the acoustic material supporting the application.

Based on previous investigations of noise complaints one needs to take on board complaints in the investigation. This led to me requesting access to several residences in proximity to an operational wind farm. My attendance and measurements found the presence of noise levels significantly greater than predicted and a unique signature subsequently found near other wind farms.

Since 2012 I have been involved in seeking to identify and quantify the acoustic signature associated with wind turbines so as to permit the necessary medical investigations to be undertaken by others.

Q.Your interviews and studies at homes of impacted persons at Cape Bridgewater are groundbreaking. Can you describe the creative process involved in your discoveries? In what way was this study/research so important?

A. On previous testing at the Waterloo wind farm I found residents could identify pulsations from the wind farm even though it could not be heard. It was something they felt rather than heard. The wind farm could be sensed when the narrow band frequencies around 4 – 5 Hz had a level in the order of 50 dB (or more).

I was subsequently approached by the operator of the Cape Bridgewater wind farm to undertake an investigation to address complaints from local residents that could not be resolved by the dBA method and was given a free hand to undertake testing to explore the concepts I had presented to describe wind turbine noise impacts.

I was given a brief to undertake measurements and determine certain wind speed and noise levels that corresponded to complaints from specific local residents. The conduct of medical studies at the same time and have a control group was refused by the wind farm operator.

I based the study on the complaints and observations by the residents for comparison with the measurement results. I took the view that the primary function was to take account of the resident's observations without ANY preconceived opinions.

I took measurements inside and outside residential dwellings and was given access to the wind farm and all operating data over a 9-week period.

I was to attend the site every two weeks to download data and meet with the residents (a house at a time) to discuss the analysis of the previous fortnight and what they had reported. We processed the diaries and the data separately to each other, then combined the results for discussion.

I trialed a diary format based upon the EPA Waterloo study to see if I could match the results. But the residents couldn't agree with the noise descriptions.

On discussing the resident's observations (with the residents) for the first two weeks I found the use of describing the impacts in terms of **Noise, Vibration, and Sensation** was accepted by the residents as a better concept.

The challenge we had was finding a way to identify a pattern in the complaints versus the operation of the wind farm. I work best in a visual format and we tried various permutations of graphical tracking of the results versus the dBA levels, the power outputs of the wind farm and the wind speed and direction.

Initially I found a pattern versus changes in the wind farm power output as the residents were only reporting changes that they perceived. I changed the reporting to 1 or 2 hourly intervals.

Based on the complaints we found certain wind speeds (power outputs) that gave rise to complaints. The challenge was then finding the sound levels that related to complaints.

dBA doesn't work. We found it correlated well with the wind speed but not with the noise from the wind farm.

We then tried 1/3 octave bands and various acoustic parameters that have been used for noise and wind farm investigations and still no trend.

It was not until we tried the complaints versus the infrasound narrow band signature that we found a trend. *And sensation came out as the major impact.*

We tried plotting the greatest level of sensation (when the residents actually left their properties or wanted to leave) and found patterns of disturbance that related to the power output of the turbines trying to start, when at high wind settings that the blades were angled to depower the turbine or changes in the power output (up or down) of over 10%.

I also noted intermittent vibrations in the floor of house 88, even during the shutdown period, that related to wind gusts. This led to vibration measurements on some turbines and in the ground on the wind farm and the residences.We have since used the Cape Bridgewater data for further testing and research.

Q. How did you convince the developers at Cape Bridgewater to turn off the turbines for your control/blind study?

A. They were trying to get the testing done before or after the planned shutdown. The shutdown was to facilitate high voltage cabling at the substation and would occur on ten days with the wind farm operating at night. I convinced them that having testing during the shutdown would be an essential part of satisfying the brief as we could see if there were complaints without the wind turbines – and get the true ambient background noise levels without any power to the turbines.

It became an essential part of the study in that it clearly showed the different acoustic signature with and without the turbines operating, that the natural environment did not have a discrete infrasound signature and that wind gusts did excite resonances of the turbines, both in terms of noise and ground vibration.

Q. What recent papers have you presented, where, and about what? We understand that you are changing the language around “noise” and wind turbine effects possibly with the eventual understanding for legislators and policy makers.

A. The Cape Bridgewater study revealed further investigations were required as the scope of the study was limited by the wind farm operator and as such was called a pilot study.

I was invited by Dr. Paul Schomer to be a member of the Acoustical Society of America Wind Turbine Working Group to discuss further investigations of wind turbine noise. The group has had sessions at the last six ASA meetings with the opportunity to present papers on the topic. I have now given 14 presentations on my on-going research into wind turbine noise.

On the technical side we have developed a graphical presentation (a movie) for showing the variation in the acoustical signature that conveys a number of concepts in the time and frequency variations of the signal. I have raised the issue of sample speed and the error in using a digital simulation rather than the original wave file recordings.

Using a digital equivalent of a time average narrow band analysis of a wind turbine signal is not the same as the original signal. Whilst having the same energy content if used for subjective testing, it is dramatically dissimilar as identified in Annex D of ANSI Standard S12.9-2016/Part 7; but this seems to be conveniently ignored by some people.

Using inaudible digitized energy equivalent signals restricted to just infrasound can only give rise to a conclusion of nothing being heard/detected. Or, using an inaudible single tone at 4 or 9 Hz and saying it is wind turbine infrasound, is completely wrong.

We modified our reverberation chamber to investigate the threshold of perception versus the threshold of hearing in the infrasound region. Headphones don’t work the same as immersing the body to the sound field. We investigated the reproduction of the wind turbine signals normal sound and infrasound in our chamber with a large baffle of speakers to find the limits of reproducing the signal.

This is where the issue of sensation comes into play. If the residents cannot hear the turbines yet they can sense them, then the Leventhall mantra of "what you can't hear cannot hurt you," is incorrect.

As in many cases residents can perceive the operation of the turbines even though they cannot hear them, we first worked on the threshold of perception of infrasound versus the threshold of hearing in one of our test chambers. The perception occurs below the threshold of hearing and has a hysteresis effect in that the thresholds are different when the levels is increased (from inaudibility) compared to going down.

I have questioned what makes up the acoustic signature or the mechanism that gives the infrasound signature. The accuracy of the analysis and whether the turbines generate infrasound and sound waves (like that of a tuning fork), or whether there was a pulsation of the sound occurring at an infrasound rate based upon the blade passing frequency. This is the number of times a blade passes a fixed point (say the tower). For a three-bladed turbine operating at 17 rpm this gives 3 X 17 = 51 times a minute or 51/60 = 0.85 Hz.

There have been a series of papers on that subject and the ability to accurately reproduce the signal in a laboratory.

We have found there are issues with the mathematics of the analysis as the signals are not sine waves, but pulses that vary in their level over time due to different loadings on the turbines and interaction of multiple turbines.

We have identified several researchers who have used digitized infrasound signals, claiming that they are actual wind turbine infrasound, to lead to the conclusion of a nocebo effect. We have tried that approach and when increasing the gain to be audible and/or speeding up the signals into the audio range they sound totally different. Why not use the recorded wave files? Why go through a process of converting the signal into a modified digital signal that is not the same?

We looked at the subjective evaluation of wind turbine noise and the issue of amplitude modulation. We found audible and inaudible modulation and that the use of stereo imaging to give (in all cases) an overwhelming preference by the test subjects when compared to a mono signal. This outcome is obvious if you go and listen to wind turbines. However, there are papers on wind turbine subjective assessment based upon mono signals. The papers presented over the last 12 months have focused on those issues and the accuracy of reproducing the test signal from wave files recorded on site.

The question of the perception of inaudible wind turbine noise was investigated for the first paper given in New Orleans last month. It seems nobody else has undertaken such an exercise and we were able to show that persons sensitized to wind turbine noise could identify the operation of the test signal even though it was completely inaudible.

Q. The "sensing but not hearing" may be oblique to some. Can you explain the process and effects on the whole person, from the unique pressure pulsing of industrial wind turbines?

A. In 2013, monitoring at the Waterloo wind farm at a number of different houses found that residents could identify the operation of the turbines at certain times and not at others. I was unable to hear the turbines, but by viewing the narrowband frequency spectrum covering the infrasound region the analyzer showed discrete frequencies associated with the blade pass frequency (the number of times a turbine blade would pass a fixed position in a second) and multiple harmonics of that frequency.

I observed that when the levels of the frequencies around 4 to 5 Hz exceeded 50 dB then there was a very good correlation with the perception of the operation of the turbines. However, such levels of noise at those frequencies are deemed to be inaudible.

What I asked residents to do, whilst I was undertaking measurements, was to simply use their hand to identify the pulsations that they could detect such that the hand moved in time with those pulsations.

This led to the concept of sensation and by communication with colleagues in America as to the limits where the perception of the operation the turbines occurred led to the rediscovery of the work in 1980 by Dr Kelley.

When I tried the diary concept for the Cape Bridgewater residents I utilized the South Australian EPA's diary format from the Waterloo study to find that the residents did not fully comprehend or agree with the diary because the descriptions associated with noise were not necessarily satisfying what the residents were detecting. I then suggested the concept of something that they sensed rather than heard or felt by tactile vibration as another descriptor that could be used. This sensing involved pressure in the head, in the throat, in the chest, feeling dizzy, feeling lightheaded, a tingling in the legs, **whatever sensation they experienced which could not be explained by something that they were hearing or a vibration that they were feeling.**

(Our note: See here for a previous article at MR regarding the Cape Bridgewater findings.)

All the residents involved in the Cape Bridgewater study agreed that the concept of sensation was more appropriate in describing what they were experiencing, and that in many cases what they had complained about as noise impacts was incorrect and was the wrong description.

When describing the concept of sensation to other people that are exposed to wind turbine noise I have received confirmation that, yes, sensation is the appropriate mechanism for describing what they are experiencing.

As described earlier, the operation of a turbine generates pulses at the blade pass frequency. Due to there being different wind speeds at different elevations above the ground then the pressure differential across a blade at the top of the swept path is different to that at the bottom. Accordingly, along the length of the blade one can imagine the windspeed and the pressure differential across the entire length of the blade will vary as the blade rotates.

For example, for a three-bladed turbine that is operating at 17 revolutions per minute, then for any fixed point on the circumference of the swept path of the blades there will be 3 x 17 = 51 passes per minute. Because acousticians work in Hertz or cycles per second, then the blade pass frequency is 51/60 = 0.85 Hz.

As frequency is the reciprocal of the timing between the pulses a blade pass frequency of 0.85 Hz means that there is a pulse every 1.77 seconds.

One only needs to listen to operational turbines to observe that the nature of the acoustic emissions generated by turbines is not one of a constant noise. One can hear the regular pattern of the swish noise which occurs at the blade pass frequency.

Spend some time at a turbine and it becomes apparent that the overall noise varies up-and-down in its level due to the different wind speeds. The character of the noise may vary in a matter of minutes due to a significant variation in the level of the noise (the amplitude) where that variation changes at the rate of the blade pass frequency.

If you examine the frequency spectrum you will find that the variations in the amplitude and the pulsations that occur affect all the frequencies across the audible range and occur below the nominal threshold of hearing which means that there are inaudible pulsating signals.

The natural environment where there are low frequency and infrasound signals generated by the wind, waves on the beach, waterfalls etc. do not exhibit this unique periodic function of a blade pass frequency, and harmonics of that frequency. This permits one to simply use the narrowband infrasound analysis to identify the operation of a turbine.

Many residents report unexplained disturbance or impacts when they are unable to hear the turbines but can identify the operation of the turbines by way of what they sense; that led me to undertake the latest research by creating inaudible wind turbine noise as recorded inside houses and then subjecting people to that noise.

As an acoustic engineer with years of investigating industrial noise complaints and complaints from the community concerning, in particular music from licensed premises, the important thing in considering impacts from any noise source is listening to the complaints, conducting measurements and observations with an open mind and then seeing if there is any relationship between those three inputs in addressing the problem.

That is the approach that I adopted in trying to understand what were the complaints from residents associated with wind turbines when on my first experience the noise was extremely low, could not be detected inside the dwelling and I didn't understand why the residents would be so vocal and genuinely distressed from the turbines.

Now I am summarizing in a relatively short space of time the result of four years of research work into what constitutes the acoustic signal from wind turbines and investigating the limitations in producing such signals. This work has been the subject of 14 presentations/papers presented to the Wind Turbine Working Group of the Acoustical Society of America. It has been a long and frustrating process to identify how to reproduce the original signal in a laboratory (and more importantly what doesn't work) that has questioned and debated what is the actual acoustic signature associated with turbines, and are we correctly measuring those signals?

Chapters 9 and 10 of the Cape Bridgewater report identified by way of the specific on-off testing of the entire wind farm the unique signature that is associated with wind turbines, and I understand that is the first time that multiple simultaneous measurements repeated on a number of occasions with turning off entirely a wind farm that this material has been obtained. A stopped wind turbine/wind farm generally still has equipment operating inside the turbines such as pumps and fans et cetera operating that in turn can radiate noise from the turbine tower and effect the "off" results, which was the case under the EPA Waterloo study.

Q. What triggers are there for sensitive or sensitized persons? Do you plan more research on specifics of these (possibly PTSD impacts)?

A. I am just a noise engineer and therefore not qualified to answer that question in terms of how the body responds to different acoustic stimuli.

What we have found is that we can present to people inaudible wind turbine noise and get a reaction whilst we can provide inaudible road traffic noise or wind noise similar levels or for that matter constant tones and not get any reaction.

We were investigating noise complaints associated with an underground coal mine that has a very large ventilation exhaust fan with an operating speed well down in the infrasound region and was subject to some level of pulsation. In an audible sense that a kilometer from the discharge point one could hear a low frequency noise around 120 Hz that over a very slow rate the amplitude of that noise would vary.

When the family that was the subject of the investigations attended our laboratory, and was exposed to a constant level and 120 Hz (pure tone) at about 50 dB there were no issues. That level of sound is clearly audible. However, when we sought to turn the volume control up and down on a repeated basis the residents noticed a difference. As we slowed the rate of turning the volume control up-and-down the sound became more disturbing, and when we attained a rate of about two seconds, the family felt very uncomfortable and left the test room.

This material was reported to the Wind Turbine Working Group at the Salt Lake meeting in May 2016 together with a movie concept that we had developed showing the variation in amplitude and frequency of the original source signal to have the acousticians immediately recognizing relationships to motion sickness.

Normally people look at the physical movement of the body in terms of vibration as to motion sickness but there was no physical movement of the body but simply a pressure wave to the body and the head which is one issue that raises the question of trigger that you have expressed.

In the Wind Turbine Working Group meeting in Hawaii in December 2016 I raise the issue of the **startle reflex,** and whether one needed to consider the holistic effect of noise vibration and tactile perception which could incorporate the entire body.

We found that residents in proximity of a coal-fired power station (15 – 30 km) experienced significant sleep disturbance when the power station was operating at low fire rates, in a run up or run down when they obtained about a 25% capacity, or if the two turbines when operating the maximum capacity had a difference of about 10 MW. Examination of the signatures during that time indicated that the 50 Hz mains frequency was subject to variation and an infrasound rate, pulsations.

It would seem that my work has shown that inaudible pulsating noise can create impacts. As such it would appear that I have provided some validation of a hypothesis provided by Dr. Nina Pierpont in 2009.

> "Wind Turbine Syndrome, I propose, is mediated by the vestibular system—by disturbed sensory input to eyes, inner ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person's sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies. Re-stating this, it appears that even low frequency noise or vibration too weak to hear can still stimulate the human vestibular system, opening the door for the symptoms I call Wind Turbine Syndrome." Pierpont 2009

In 2012, from my initial analysis and investigations of complaints in relation to wind facilities, I was of the view that we needed to identify the acoustic signature associated with operational wind turbines, and only when that signature had been identified and able to be reproduced, could you then move to the next stage, which would allow the medical investigations into wind turbine noise.

The problem that existed in 2012 was that there be no medical studies to identify the impacts of wind turbine noise (a common statement from the wind industry). However, there is equally the same position that there are no medical studies to identify that there are no impacts from wind turbine noise.

On a statistical basis whilst adverse impacts attributed to wind turbines represent a small proportion of the community, the proportion of the community affected is more than a background proportion and indicates that there is a statistical anomaly that supports a problem.

For the people who are adversely affected by wind turbines to the extent that it affects their daily lives and in extreme cases causes them to abandon their homes, it is clearly a problem. If one restricts the catchment area for a community to be within 10 km of a wind farm (and not as in some studies, consider the community out to 100 km away), then on the restricted catchment area on a statistical basis there is a high proportion of the community being affected.

Where do we go from here? It seems we have a facility that can faithfully reproduce various acoustic signals across the audible frequency range and in a limited capacity we can reproduce infrasound levels in a test environment. We are presently exploring better quality digital to analog converters to overcome some technical limitations.

With our recent pilot study results if funding can be provided we would seek to rerun the study but with say 50 test subjects who are being sensitized to wind turbine noise but at the same time we would have appropriately qualified people undertake medical monitoring of the test subjects including EEG monitoring. We would not only just examine wind turbine noise, but we would compare the general environmental noise (also inaudible) that is often used as a comparison to wind turbine environments.

Q. Why are some persons near projects impacted, and others less so? Is it possible that some are impacted without knowing it long term? If so, what might those health impacts be?

A. In 2015 I presented a paper to the Wind Turbine Working Group of the Acoustical Society of America where I raised the matter of **'sensitization over time.'**

Over the last six years I have attended various wind farms on a number of occasions as part of my research work an investigation into wind turbine noise. I have met residents and have stayed at their houses several times over the years; it seems to me as a general observation that the people become more sensitized to the operation the turbines in that they are able to detect the operations at a lower level than previously, and that in the number of households more members of the household have been able to detect sensations or were being impacted by the turbines than on previous site visits.

The residents report a greater sleep disturbance over time and more people have had to abandon their homes.

For some people when abandoning their homes and residing at other locations there is an improvement in their overall demeanor and well-being and from my observations their conversation appears to be more normal and not exhibiting (to me) signs of depression.

However, for some people there are still lingering issues of impacts and the degree of sensitization that has developed has become affected by other "normal" noise sources such as traffic.

At the New Orleans Wind Turbine Working Group meeting Melissa Ware (who has a hearing impairment and was one of the participants in the Cape Bridgewater study) presented how she has been impacted because of the turbines.

Figure 4.3 of the WHO 2009 European night-time guidelines identifies how ongoing noise disturbance can lead to health impacts and sites cardiovascular disease as one possible outcome. The WHO discussion in Chapter 4 in relation to health impacts, primarily related to road traffic and aircraft noise, should be placed in the context of the suggested dose response curves to indicate impacts from wind turbine noise occurs at lower thresholds than that of Road Traffic or Aircraft Noise.

Q. You have testified in many instances, in various countries, about these findings, and the very real and verified impacts on "victims." Have these testimonies had impact on policy changes?

A. The wind industry relies upon compliance with guidelines or criteria issued by regulatory authorities.

In many cases the court relies upon guidelines or criteria issued by regulatory authorities, despite hearing evidence from residents as to the extent of disturbance they experience because of operating wind turbines.

In the end the court or tribunal uses the escape clause that it is not for them to set guidelines or criteria, but it is the regulatory authorities responsibility and therefore they must abide by that criteria.

So, to date there have been no policy changes as a result of my investigations or the many "victims'" impact statements to Courts and Tribunals. The escape clause is the published guidelines and standards.

When one examines the guidelines or standards used in Australia for wind turbines, it becomes obvious that there is no scientific basis to identify the noise targets proposed for wind farm facilities with respect to an acceptable level of noise that will not give rise to disturbance or unacceptable impacts for residents.

This fact is obvious because there are no scientific studies into determining the dose-response curve to identify the level of annoyance that would satisfy 90% of the population or to identify the level of noise from wind turbines that would not give rise to sleep disturbance.

The regulatory authorities are the ones who should be accountable to the community for permitting adverse impacts and in turn health impacts.

Policy change in terms of guidelines and standards for wind turbines in Australia, or in America, will simply not occur if left to the regulatory authorities. For example, the community of Waterloo in South Australia have publicly expressed no confidence in the South Australian EPA who steadfastly support their guidelines as being appropriate, without providing any material to support the basis of those guidelines other than simply referring to WHO guidelines (based upon road and air traffic).

With the mounting evidence of the negative impacts created by wind turbines, and if one can get to the point of the medical studies to confirm the actual impacts, then one could expect damages claims against the regulatory authorities for their lack of scientific rigor and failure to apply the precautionary principle.

In late last year, the Administrative Appeals Tribunal (a federal Judicial body) in relation to the charity status of the Waubra Foundation, was presented with a significant degree of evidence in relation to wind turbines creating adverse impacts on the community and the inadequacy of current guidelines to protect the community.

The Waubra Foundation has assisted members of the community in seeking to understand the ramifications of wind turbines and to be in effect the first point of contact to obtain information or advice in relation to wind turbines.

The foundation lost its charity status, but it is of huge significance that the Administrative Appeals Tribunal clearly stated that dBA was useless. *The AAT found that the operation of wind turbines did generate both audible and inaudible sound, did create an impact on the community that gave rise to disturbance and that more research (to that proposed and supported by the Waubra Foundation) should be undertaken.*

The week following the AAT decision, five papers from Australians were presented to the ASA Wind Turbine Working Group, of which the first paper was my recent one concerning the pilot study of inaudible wind turbine noise being detected by residents who are sensitized to wind turbine noise.

Q. In your response to the previous question you referred to the need for appropriate criteria for wind turbines and noted that there are **'no criteria** based upon wind turbine studies.' Some people say the Health Canada study provided that information. What is your view of that study?

A. I am unable to comment on the socio-acoustics or the medical components of the study, but understand there has been significant criticism of the Health Canada study by persons appropriately qualified in those areas. Master Resource has published some of those; other criticisms are listed here.

The authors of the Health Canada study identified that it was only the site specific and should not be used as generic conclusions.

The study had limitations on the age of people involved in the study and left out houses that were vacant. Community representatives have identified that a high proportion of the vacant houses related to people who had left the area (abandoned their homes) because of the wind turbines.

The ASA Wind Turbine Working Group (Acoustical Society of America) was advised in the middle of last year that there would be an investigation undertaken by Health Canada in conjunction with the community to look at the people who are sensitized to wind turbines and/or who had abandoned their homes, but that material has not been published.

The determination of the actual noise from wind turbines when utilizing the dB(A) or the dB(C) parameter is difficult in the real-world environment, which is the position that we found in the Cape Bridgewater study.

A problem with the Health Canada study is the lack of actual acoustic or measurements to relate to the community response material in that the **study relied upon predicted noise levels** and not actual noise levels. As such the Health Canada study did not (and could not) provide any validation of the predicted levels versus the actual wind turbine noise levels.

The analysis to show a constant 15 dB difference between dB(A) and dB(C) is simply from a mathematical analysis of distance attenuation using a constant spectrum without any adjustment for excess attenuation over distance due to atmospheric absorption and this can only relate to a theoretical exercise for external noise. Due to the attenuation characteristics of different building envelopes, the internal noise level from wind turbines cannot be simply extrapolated from an external noise level, and this is an issue of concern.

The interpretation of annoyance excessive to background levels as published by the principal author of the Health Canada study, simply defies logic as to what it means and ends up contradicting other acoustic components of the study.

Some of the ambient noise levels that have been provided in the Health Canada study seen to be extraordinarily high if one is considering a rural environment. Yet there is no information to identify the nature of the acoustic environment and the influence of agricultural activities or traffic noise that may have required some of those data points to be removed.

The study appeared to be constructed around existing general acoustic criteria and other than some excellent work in terms of infrasound monitoring (then reported upon by others), there does not appear to have been an attempt to undertake a lateral thinking approach in looking at other indices or issues that may be giving rise to the reported disturbances.

Q. It seems that the primary complaint that first occurs with wind turbines is sleep disturbance. The WHO 2009 European Night Time Guidelines show in Figure 4.3 that on-going sleep disturbance becomes a health impact. The WHO reports that some of these, by no means the exhaustive list, are attributable to poor sleep patterns, often a result of environmental noise: fatigue, lack of ability to concentrate, memory impairment, lack of energy, proneness to errors or accidents, tension, social or vocational dysfunction, headaches, and gastrointestinal symptoms related to worry about sleep.

In your opinion is sleep disturbance from wind turbines a relevant matter that should be investigated?

A. Most definitely YES.

If we have guidelines or standards that claim they have criteria to protect against sleep disturbance or identify the sleep disturbance is an adverse impact, or criteria that purport to protect the amenity of the surrounding community from adverse noise impacts then surely there must be some data to substantiate the criteria that have been nominated for wind turbines.

However, I have yet to see any material/data that relates to the current capacity of wind turbines being installed around the world. A few papers related to studies at the beginning of this century in Sweden and the Netherlands on relatively small wind turbines, indicated dose response curves significantly lower than that applicable to road traffic noise (in urban areas) or aircraft noise.

Wind turbines are generally located in rural areas then the acoustic environment of rural areas, and therefore the identification of the acoustic amenity that residents in those areas experience must be different to that in an urban environment.

From my investigations and examination of various studies into wind turbine noise, it seems to me that the following questions need to be answered by the Regulatory Authorities in relation to the criteria that those authorities have issued to permit wind turbines to operate in proximity to residential receivers. It does not hurt to repeat these, if some have not understood the basic nature of these requests for sources and studies.

1. > Please provide studies upon which the wind turbine/farm criteria have been developed?
2. > Please identify the noise source(s) that have been used in the studies related to question 1?
3. > Please provide the dose-response data related to wind turbine/farms on which the criteria are based, and the corresponding level that represents 10% of the population that is highly affected?
4. > The most common complaint from residents relates to sleep disturbance. Please provide the studies of wind farm noise that identifies the noise (in any relevant acoustic index) that gives rise to sleep disturbance?
5. > Please provide studies of wind farm noise that identify the noise level (in any relevant acoustic index) that will not give rise to sleep disturbance.
6. > Please provide studies of wind farm noise that identifies the noise level that would protect the acoustic amenity of residents in proximity to wind farms.
7. > In light of the above, please identify who would be liable (in a damages claim) for the consequences of adverse impacts.

I came up with the above questions in December 2016 and to date, neither I nor community representatives in Australia have been able to get any response from the regulatory authorities or a Commonwealth Government appointed Wind Farm Commissioner to these relatively simple questions.

Those same questions were put to the Administrative Appeals Tribunal, but they were unable to answer those questions simply because the data is not available.

The provision of scientific data to identify the dose-response curve and sleep disturbance criteria in relation to wind turbine noise would then place in context the appropriateness or otherwise of criteria issued by Regulatory Authorities.

We thank Steven Cooper for his detailed and extremely current exploration and overview of wind turbine "noise" and again, his studied reminders of the profound relationship between sleep and health. As Mr. Cooper indicates yet again, let developers or wind promoters provide the dose response curve for sleep disturbance, provide all the data that should be tabled, in full protection of human health, before contemplating building wind factories.