

The inadequacy of the A-frequency weighting for the assessment of adverse effects on human populations

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ABSTRACT

The A-Frequency Weighting has been used for more than 50 years as the primary metric for the determination of adverse effects of exposure to sound and noise for the human population. This paper outlines why this anachronistic measurement metric is inappropriate for classification of acoustic exposure in humans. Acoustic energy impacts on human physiology in a number of different ways through significantly different neurological pathways in addition to simple hearing (audition). The long-term effects of other biological pathways have been consistently overlooked because of the health and safety focus that espouses only loud noise is dangerous. The current paradigm considers that the only adverse effect resulting from acoustic exposure is damage caused through high-level acoustic bombardment (high sound pressure level). This paper outlines some of the other mechanisms that are involved with adverse human health effects as a result of industrial noise exposure, including very low-frequency sound and waveform characteristics.

INTRODUCTION

The Infrasound Issue

Infrasound (airborne pressure waves with a frequency of <20 Hz) has existed in Earth's environment since outgassing at the time of the Earth's formation, and all life forms have evolved in its presence. On the other hand, anthropogenic (or 'man-made') infrasound has been blamed for the adverse health effects reported by many groups of people over recent decades. With the increase in the number of new wind turbine installations around the world, so are complaints increasing for residents living in their vicinity. Considerable controversy has resulted amongst a number of professionals in the field of acoustics [1] and public health [2]. While not uncommon for professionals in any field to have disagreements over detail, rarely do these discussions so severely and directly impact public health, with devastating consequences for families, livelihoods, farm animals and pets.

Historically, acousticians defend the contention that infrasound cannot be heard by humans and, therefore (for that reason alone), cannot be responsible for adverse health effects. Ever more frequently, however, families living near industrial wind turbines (IWTs) present with a clinical picture claimed to be caused by elevated levels of infrasound in their homes. Significantly, amongst families living near IWTs all over the world, the *same clinical picture appears*. While it is true that the 'jury is still out' with respect to the adverse health effects of infrasound emanating from IWTs, the significant growth of the number of families reporting severe adverse health effects now represents a scientifically and statistically robust group. Continuing to ignore the problem is unethical and medically reprehensible.

Acousticians and Public Health

In the vast majority of court proceedings involving IWT-related residential noise complaints, an acoustician is required to verify whether or not noise levels are in compliance with legislated permissible exposure levels (consents). In cases where infrasound is an issue, acousticians are also being asked to opine on the health effects of low-frequency and infrasound-rich environments. Acousticians are professionals whose expertise lies in the measurement of sound, not the diagnosis of medical conditions. Their training is largely of a physical, not biological or physiological nature. They profess considerable knowledge of the instrumentation and its use, but not of the ability to determine human response, either psychological or physiological. Nevertheless, their input in public health debates has been accepted, and medical professionals asked to pronounce on the impact of infrasound on health have on occasions gone to the extent of deferring their response to the local acoustician.

With regard to matters of public health, there is a potential conflict of interest involving acousticians employed by the wind industry who then pass comment on the potential adverse health effects. While acousticians are qualified to pass comment on the acoustical emissions of wind turbines and also whether or not those emissions fall within the permitted consent, they are not qualified to pass comment on matters of human health. This conflict of interest has the potential to affect other anthropogenic noise sources also.

In view of the fact that anthropogenic environmental noise is emerging as one of the major public health concerns of the twenty-first century, such conflicts of interest and the inappropriate reliance on a particular class of professionals has the potential to degrade public health. As a result of the drive to renewable forms of low-carbon energy sources, wind turbines are being placed ever-closer to homes in once-quiet rural environments; therefore it should come as no surprise that the number of health-related complaints is increasing [3]. A number of authors have documented complaints about sleep disturbance and adverse health effects [4–6].

Numerical Compliance

The current debate places many acousticians at odds with "We, the people." In acousticians' defence, legislated 'compliance' values for acoustical environments are based on a single numerical value, usually expressed in dBA. Figures 1 & 2 show examples of these compliance values for occupational and environmental situations respectively.

These values can differ slightly from country to country, but rarely, if ever, are they expressed in a metric other than dBA. In Europe, environmental noise has been characterised by three parameters: L_{day} (07:00-19:00), L_{evening} (19:00-23:00), and L_{night} (23:00-07:00). The variable L_{den} (Fig 2) refers to the weighted average of these three parameters, while L_n refers to the night-time level. Peak levels of noise (L_{peak}) in occupational environments and tonal noise in environmental assessments are also taken into consideration by legislative bodies. Sensitive zones are those containing residential areas, schools and hospitals, while mixed zones are all other areas.

Noise Level dB(A)	Exposure Time
85	8 hours
88	4 hours
91	2 hours
94	1 hour
97	30 mins
100	15 mins
103	7½ mins

Figure 1: Exposure standard for occupational noise for Western Australia [7].

Zone Type	Noise Level (dBA)	
	Lden	Ln
Mixed	≤ 65	≤ 55
Sensitive	≤ 55	≤ 45

Figure 2: Exposure standard for environmental noise in Portugal [8]

These are the ‘compliance numbers’ that acousticians defend in court proceedings when residential noise complaints are an issue. Where is the information on the infrasound content of the environment? Indeed, where is there *any* information on the frequency content of the environment? The following sections will review the historical reason for why acoustic environments have (erroneously) been considered as fully characterized with a single numerical value expressed in dBA.

BRIEF HISTORICAL BACKGROUND

The Development of Loudness Units and the deciBel

In the early part of the 20th-century, the study of acoustics was greatly boosted by the American Telephone and Telegraph Company (AT&T) who employed Harvey Fletcher from the Western Electric Company. Fletcher was tasked with improving the quality of reception in the telephone, which required the development of both a metric and technology. Standardisation of units was not yet common, and the unit for measuring resistance (transmission unit, TU) was related to one mile of standard cable — a value that varied with temperature and frequency, not to mention the metallurgy of a ‘standard’ cable. Fletcher came up with a new concept — the ‘sensation unit,’ SU — that was related to human hearing response. Based on a power series compared to the voltage that produced the minimum audible sound, this unit was initially called the Loudness Unit, and was later rejected because it was a comparison ratio, and not a unit metric. [9]

On February 8th 1924, AT&T and the Western Electric Company created the Bell Telephone Laboratories (Bell Labs) in honour of the recently deceased Alexander Graham Bell. In 1927 the suggestion was made to call the Transmission Unit, the Bell. Some initial reticence was expressed by some telephone engineers, stating that “Bell” was too close to the French “Belle,” the final name chosen was the “Bel.” The tenth of a Bel became known as the deciBel which has stuck with us ever since even though it too was a comparison ratio, but of sound pressure level. The upshot was the development of the Wente microphone, an instrument to measure sound intensity units based on an arbitrary sound pressure similar to that of Fletcher’s voltage that produced the minimum audible sound. And so the concept of the sound intensity meter was born out of the Acoustical Society of America that was founded in 1928 with Harvey Fletcher as its first president.

The first sound level meters were large, consisting of a condenser microphone, a valve amplifier and a valve voltmeter, with a logarithmic scale covering the voltage range of one sensation unit split into 10 segments. The immediate problem was the movement of the meter’s needle, which could oscillate to such a degree as to be unreadable, so some sort of

damping was required. The target was to get the needle to move over its entire scale in one second over the range of 1 Bel, divided into decibels (referenced to 10^{-12} watt / m²).

Around this time the first audiometers were also being developed, with voltage settings linked to sensation units. The focus of research at this time was speech clarity; hearing studies and audiometers were the only instruments used for comparison studies. It is important to note that at this time, just under one hundred years ago, there were no standards to give reference to voltage or power, so researchers used different measures, and the accuracy of their measurements were also questionable with the instrumentation of the time. The Acoustical Society of America [10] introduced the first embryonic standard for sound level meters in 1936. So while there was good progress in measuring power levels in electrical circuits, there was still some way to go to translate this into meaningful measurements with respect to human physiology and hearing.

Determining Equal Loudness Curves and the A-Weighting System

In order to address the problem of industrial noise in the early 20th century, measurement was essential, as was a metric. At that time, researchers were critically aware that the readings on a sound level meter did not represent how loud or intense the sound was with respect to the subject's perception of hearing. It was determined that some sort of modification to the circuitry was required to create a measure of loudness.

From a biomedical perspective, the concept of loudness is subjective. Each individual has a different physiology and responds differently to sound. This response is not stable or constant minute-to-minute, let alone over the lifetime of the individual, so the concept of developing some universal hearing loudness concept is defeated on first principles. These serious constraints notwithstanding, it is acknowledged that some average measure of loudness would have some value, not only for comparison and medical diagnostic purposes, but for regulation of noise levels for public health.

In the late 1920s, Harvey Fletcher and Wilden Munsen were to develop the concept further by experimentally determining what they termed equal loudness curves. They selected 23 healthy, young males, whom were *assumed* to have good hearing. These subjects were exposed to a series of different, single, pure tones at different levels of loudness and asked to score the sounds for equal loudness. The tones, produced by valve oscillators and amplifiers, were presented to the listener by occluded (covering the ear) headphones. The basic range of 20 Hz to approximately 16 kHz was used because those were the limits of the equipment at the time.

It is important to note two significant constraints with respect to this experimental procedure. Firstly, the sounds presented were 'pure' sine waves, that is, sounds that are close to the sound produced by a flute or an organ pipe. These would have limited harmonics (and then predominantly even harmonics). Secondly, the headphones were occluded, that is, closed around the ear of the subject. This is a very unnatural way to listen to a very unnatural sound. Pure tones do not actually exist in nature, nor is there ever one tone in isolation.

The numerical results of this 23-subject experiment became known as the Fletcher-Munsen Curves, and are the basis of the modern, ubiquitously used, A-Weighting system (Fig 3). The relationship between loudness and human perception is complex, however the primary basis for public health and safety is based upon loudness, which is in itself problematic at the very least.

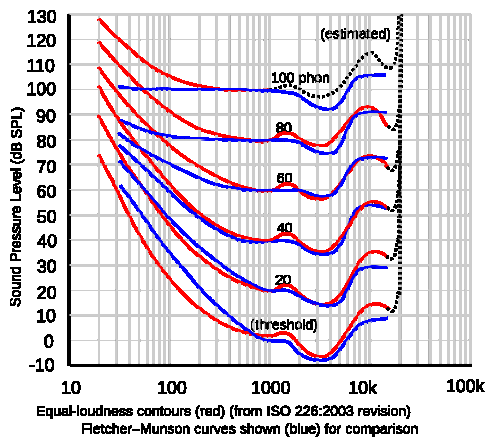


Figure 3: Fletcher Munson Curves [11]

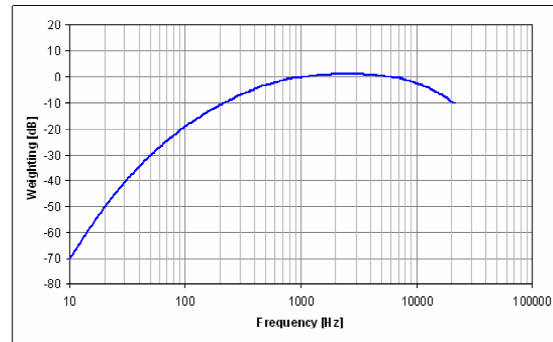


Figure 4: A-weighting frequency response curve [12]

The minimum pressure required for humans to perceive sound at 1000 Hz is 20 microPascal, with an intensity of 10^{-12} Watt /m², corresponding to 0 Phon and to 0 dBA, as per figures 3 and 4. For all its shortcomings, the A-Weighting has endured for decades and has become the *de facto* standard for environmental noise measurement. But is the A-weighting sufficient for all circumstances? The answer is an emphatic “No”. The principal failing is that it heavily discounts all frequencies below 1000 Hz and ends at 20 Hz. This is a consequence of the equipment of the 1920s and 30s that has remained to this day. The range of human hearing is (almost universally) defined as existing between 20 Hz and 20 kHz, regardless of the fact that humans can and do hear above and below those levels. *The standard frequency range for human hearing is simply an approximation for the sake of simplicity.* It in no way reflects the reality of hearing. The implications for public health are considerable, when based on this limited approximation of human hearing.

FREQUENCY

In Airborne Acoustics

The parameter *frequency* is closely associated with the physical behaviour of the environment. In the natural environment, impedance (resistance to alternating energy) is also relevant to the transmission of acoustic waves in air. Airborne pressure waves (sound) are attenuated (impeded) differently depending upon their frequency. In essence, high frequencies are attenuated most easily in air, while lower frequencies are not attenuated as much. As a general rule of thumb, mid to high frequencies (with respect to human hearing response) are considered to attenuate at the rate of 6 dB per doubling of distance. Low frequencies, on the other hand, attenuate closer to 3 dB per doubling of distance. For this reason, lower frequencies of sound travel long distances and are used by many human cultures including the alpine horn used to call farmers in from the fields in northern European countries, and church bells calling parishioners to worship.

In Neurobiology

The concept of *frequency* is also important to understand the neurobiology of brain function. Neurophysiology of the brain is a vast topic but, from the perspective of environmental response and public health, it is the integrated response that it performs that is of interest.

The brain is a difference engine. It continuously adjusts itself to varying input levels. As the body experiences the environment, it encounters temperature changes, light and other

weather-related changes, geographical and texture-related changes, and of course, acoustical changes. Various sensors at the extremities of the body provide information regarding temperature, touch and light information. Internal sensors provide information related to position, posture and motion. These include the vestibular system of the inner ear, and proprioception sensors in the muscles to indicate position. And, of course, sound is sensed via the eardrum and cochlea. All these various sensory systems provide a continuous influx of nerve impulses to the brain. These sensors must be constantly working because environmental variables are continuously changing, as are the environmental circumstances they represent that may be critical to survival.

Neuronal communication is based on a frequency-modulated system, not amplitude-modulated. In this way, each nerve connected to a sensory system—be it a pacinian corpuscle, a retina cell or a hair cell in the cochlea—is continually firing. Only the rate varies. Cray fish, for example, are able to detect the difference between a smallmouth bass swimming towards them with its mouth closed or open by the change in the very low frequency of its swimming wake [13]. In humans, nerves from pacinian corpuscles (for example) fire continuously, the rate being determined by the amount of pressure on the spiral membranes. When little pressure is applied, essentially zero at atmospheric pressure, the firing rate is slow. As pressure increases, the firing rate increases proportionately (although non-linear events can also occur). Thus, the brain is constantly receiving information in the form of neural pulse trains from each particular sensor, of constantly varying frequency.

The brain, constantly inundated with all sensors reporting the status quo, interprets these sensory-output pulse chains by determining the difference in time between impulses. Since the firing is continuous, the only difference being the frequency, the brain's way to interpret the environment is to determine the difference in frequency—hence it operates as a difference engine. Airborne pressure waves that induce pathology are defined by the WHO *International Classification of Diseases* as inanimate mechanical forces [14]. As they impinge upon the human body, they are only *heard* (i.e., that is consciously perceived), in certain frequency/amplitude ranges. However, the biological organism, via the peripheral sensors, is receiving information at all frequencies, whether or not it is acknowledged by the human sense perception. The brain is constantly receiving neural information, regardless of conscious acknowledgement or not.

In Legal Proceedings

A common belief is that “What you can't hear can't hurt you” [15]. Clearly, when Fletcher and Munson were trying to get the best telephone acoustics, what was *not heard* was, indeed, irrelevant for their study. This meant that the equipment limitations of the time, requiring a cut-off at 20 Hz, were perfectly acceptable. This mind-set has trickled down into modern environmental acoustics (Fig 2) and occupational medicine (Fig 1). The first bone of contention between acousticians and “We, the people” is, therefore, the justification for the use of the dBA metric and consequent non-evaluation of infrasound and low frequencies.

BRIEF DISCUSSION OF HEALTH COMPLAINTS

Acousticians and Health Complaints

From Europe to the Middle East and from North America to New Zealand, entire communities are being forced to live in the vicinity of large IWT developments; a large proportion of these families are complaining of *the same* health-related symptoms. In many court proceedings regarding residential noise caused by IWTs (in which the authors have served as expert witnesses), acousticians hired by industrial developers have equated medical anamnesis (a patient's preliminary case history, either medical or psychiatric) with *anecdotal stories*, thereby

attempting to downplay the importance of patient complaints. Here is another important bone of contention between acousticians and “We, the people.” The former (arguing on behalf of their employers) allege that patient complaints are merely anecdotal stories and, therefore, of no value.

The adverse reported health conditions manifested by families living amongst IWTs have also been classified as the result of a *nocebo effect*. [2,16] This term has been picked up by some acousticians who, in court, use the concept as an alternative explanation of patient complaints, and in accord with their opinion that there are no health effects in humans residing in the acoustic environments in question. The following sections will address these perplexing (at best) positions that have been frequently defended by acousticians hired by industrial developers.

The Importance of the Anamnesis - Personal Medical History

It is difficult to know when the first physician considered public health rather than the health of the individual but, in recent times, Bernardino Ramazzini (1633–1714) was the first to commit to writing about it. His now famous work, *De Morbis Artificum Diatriba* (Discourse on the Diseases of Workers), was first published in 1700 in Modena, Italy. Arguably Ramazzini’s greatest contribution, the book on worker diseases outlines the various hazards workers faced including dust, metals, other chemicals, adverse outcomes as the result of repetitive or violent movement (today called Repetitive Strain Injury or Occupational Overuse Syndrome), unusual postures and other disease-causing agents across 52 different occupations. While a proponent of the great Hippocrates, famous for taking patient histories, Ramazzini suggested adding the question: What is your occupation?

When a patient reports health complaints, the medical doctor is trained to distinguish between *signs* and *symptoms*. Symptoms are what the patient complains about, while signs are what the physician observes in the patient. The origin of some signs and symptoms can be traced to the patient’s prior occurrences in life, including their occupation. This is where an anamnesis is of fundamental importance. It provides information to the physician that can clarify many of the symptoms reported and of the signs observed. For example, the patient complains of a sore toe can be classified as ‘hearsay’, but if the doctor touches the toe and that initiates a pain response, then the *subjective hearsay* of the patient is given more credence because the empirical, objective observation by the physician, also now exists. In clinical medicine hearsay *is* anamnesis. When the patient’s complaint is a headache, there may be no easy way to ‘prove’ this objectively, but at the end of the day the physician will make a diagnosis and treatment based on their experience and knowledge, and on the strength of belief in the patient’s subjective description. Medical diagnostic tests (invasive or non-invasive) can be prescribed when the physician requires a differential diagnosis (distinguishing diseases that have similar signs and symptoms), or to confirm or negate a suspected diagnosis.

It is important to note that anamnesis is defined in medical dictionaries as the ‘case history’. Further, that it is a holistic assessment of all factors affecting a patient’s health status, including information about social, cultural, familial and economic aspects of the patient’s life, as well as *any other component of the patient’s lifestyle that affects health and well-being*. The case history is designed to assess the effects of health care deviations on the patient and the family, to evaluate teaching needs and to serve as the basis for an individualised plan for addressing wellness. In summary, anamnesis is the medical history information obtained from the patient to aid in establishing a medical diagnosis and developing a treatment plan. Clearly anamnesis has far greater strength and relevance than the somewhat pejorative connotation of ‘hearsay’. *Indeed, it is the very basis of the practice of clinical medicine.*

When wind industry representatives, or acousticians, declare that an individual's response to IWT noise is due to the nocebo effect or some other psychosomatic or psychogenic factor, they are essentially making a diagnosis that they are not legally entitled to make. It is the general acceptance of this inappropriate stance that needs to be addressed by the wider public and the law courts. You would not go to a dentist to address the problem of a broken leg, so why would you rely on a pseudo-diagnosis of your health status made by a wind turbine representative or an acoustician? It is simply inappropriate. Wind industry representatives and acousticians must be taken to task about their unethical practices in this regard. Further, if medical practitioners made such sweeping diagnoses without actually seeing the patient and conducting the appropriate anamnesis, they would be liable for a medical malpractice suit. However, both wind industry representatives and their consultants continue to make such sweeping diagnoses in both the media and the literature without ever seeing the complainant (patient).

There is another side to the case history that is often overlooked by those not directly involved in the practice of medicine (or science); that it is based on statistics and empirical observation. Every new disease or malady was, initially, nothing more than conjecture based on a few observations. It is only from a number of observations that a pattern may become apparent (for example, the discovery of AIDS, the occurrence of infant-limb malformation in mothers medicated with thalidomide, malignant mesothelioma in asbestos workers or smoking-related lung cancer). John Snow (1813–1858), often referred to as the 'Father of Epidemiology,' began to apply statistical methods to the public health cholera epidemic in London and, today, statistics is an important component of medicine and public health. The accumulation of similar case histories can, and does, give rise to the eventual discovery of a new disease or syndrome. This much we learn from history.

One final but critical point is that frequently in medicine, diagnoses are made and treatments prescribed as a direct result of the patient's claims (hearsay?), without further clinical investigation. This must put additional weight on the testimony of patients, elevating the importance of proper anamnesis above the pejorative 'anecdote' so often attributed to them by the wind industry and their contractors.

Infrasound Exposure and Sleep

When examining the effects of a physical agent of disease upon a population, it is important to distinguish between *immediate* and *long-term* effects. Within the context of IWT developments, a common first complaint among families is disruption of the sleep cycle. This is frequently translated into the statement: "I wake up tired." Other populations exposed to infrasound generated by other industrial complexes refer to the same complaint: "I wake up tired." For the layperson, everyone "wakes up tired" at some time or another in their lives. But in the case of families that have infrasound-contaminated homes, this can occur in all members of the family, and every day for many months or even years. Constant fatigue is generally the directly ensuing consequence.

Long-term sleep deprivation, in terms of quality and quantity, has widespread and serious consequences on health. The World Health Organization (WHO) takes a strong stance on sleep as connected to human health and wellbeing that has been defined as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." [17] Quite clearly, the WHO states:

If negative effects on sleep are to be avoided the equivalent sound pressure level should not exceed 30 dBA indoors for continuous noise. [18]

And:

If the noise is not continuous, sleep disturbance correlates best with the L_{Amax} and effects have been observed at 45 dB or less. This is particularly true if the background level is low. Noise events exceeding 45 dBA should therefore be limited if possible. [18]

Finally:

To prevent sleep disturbances, one should consider the equivalent sound pressure level and the number and level of sound events. Mitigation targeted to the first part of the night is believed to be effective for the ability to fall asleep [...] [S]leep disturbance from intermittent noise levels increases with maximum noise level. Even if the total equivalent noise level is fairly low, a small number of noise events with a high maximum sound pressure level will affect sleep. [19]

Clearly, there are a number of factors at play in regard to sleep effects as a result of noise exposure: a) Both continuous and intermittent noise affects sleep quality and duration; b) Sleep disturbances correlate well with increasing sound levels; c) Noise effects on sleep include changes in sleep patterns and reduction of rapid eye movement (REM) sleep; and d) Subjective effects include difficulty in falling asleep, poor sleep quality, headaches, and tiredness.

Sensitive groups have been identified including shift workers, the elderly, and people with physical or mental disability and disease. Often there are road signs near hospitals advocating for quiet, and some bylaws have special zones for hospitals that have reduced noise limits (sensitive zones). But there is one other factor which goes to the heart of much of the modern problem with respect to low frequency noise in general, and infrasound in particular:

When noise is composed of a large proportion of low-frequency sounds a still lower guideline value is recommended, because low frequency noise (e.g. from ventilation fans (including HVAC systems) can disturb rest/sleep even at lower sound pressure levels [...] guidelines should be based on a combination of values of 30 dB $L_{Aeq, 8h}$ and 45 dB L_{max} . [19]

In summary, noise can have a significant negative effect on sleep. This relates to average noise levels, peak intermittent levels and sound quality, i.e. spectra. It is not by chance that sleep deprivation has been used as a form of torture by many cultures throughout the millennia.

Habituation

A common countermeasure to persistent noise is that of habituation. Habituation is the body's response to repeated stimulus, from any group of sensory cells, that is no longer perceived as important therefore no longer consciously perceived. There are many common examples of this. People who live near a railway line can get used to the sound of trains and no longer take notice of it. Similarly, stories abound about shipping personnel who sleep well while the ship engines are running, but who awake the instant they stop operating. As explained by David Walsh, Head of the Auditory Discipline & Population Health Section, Faculty of Medical and Health Sciences, Auckland University, New Zealand to mainstream media:

The auditory system has evolved to act as a warning system for our bodies. It's a way of alerting us to potential environmental threats. Sound is transmitted through the brain stem and it gets into the limbic system of the brain, which is where emotions are processed. If you go back a few hundred years, it's what stopped us getting eaten. [20]

Humans are 'hot-wired' to react to acoustical phenomenon. This is a critical point with respect to public health. Airborne pressure waves are important to the biological human and their amplitude does not have to be perceived as 'loud' to initiate neurobiological and physiological responses. In fact, the minimum pressure (at 1000 Hz) required for humans to perceive sound is 20 micro-Pascals. The impinging airborne pressure wave with these characteristics causes the tympanic membrane to be displaced by a mere 0.05 nm and that miniscule movement can be perceived by the human brain as 'sound.' At 100 dB the tympanic membrane is only moving between 70 to 100 nm, which is about the width of a human hair [21].

In the two habituation examples given above, it becomes obvious that the sleep cycle appears to be uninterrupted if no *threat* is deemed present by the sleeping brain. While physiological habituation can, and does, occur on a moment-to-moment basis, when a sudden change in pulse rate from some afferent sensory neurons is registered by the brain, it can result in a very rapid response if certain criteria are met.

In the case of wind turbine sounds, the critical part of the spectrum suspected of causing the reported adverse health effects is the low-frequency and/or infrasound regions. The other problem may be amplitude modulation of the broader spectrum of wind turbine emissions that are modulated at infrasound rates. In either case the salient fact is that there is no evidence that mammals, including humans, are able to habituate to very low frequency sound, or amplitude modulation where the modulation frequency is in the infrasound or low-frequency range. This is thought to be due to the importance that such frequencies have in the natural environment.

In the natural environment, very low frequency sound and vibration is usually a harbinger of danger, e.g. a storm or earthquake. Accordingly, if animals were able to habituate to these natural danger signals, there is a significant chance that death could result due to the animal failing to take evasive or protective actions. This trait of responding to low frequency and infrasound has been conserved through evolution, so it is reasonable to believe that there is an explanation for this, at least in the Darwinian model of evolution and natural selection.

Hearing is the one sense that never sleeps, for the very same reason of self-preservation. While hearing and the response to certain sounds may be attenuated during sleep, the self-preservation functions of the reptilian hind brain do not completely shut down which is why sleep is so easily disturbed, particularly in response to low-frequency sound. Failure to awake to a danger signal could easily result in death, ergo, those animals that survive to replicate and continue the species are those that can perceive and respond to low frequency and infrasound environmental cues and react appropriately. Refer to the comments of David Welch regarding hearing quoted above: "It's what stops you being eaten."

Anecdotes, 'Nocebo Effects' and the Scientific Method

Most noise measurement professionals do not have sufficient knowledge or training to classify patient's complaints as either anamnesis or anecdotal hearsay. Individual and familial medical histories are 'anecdotal' stories to them because they lack the knowledge to identify clinical symptoms, observe clinical signs, interpret the conjunction of this clinical information, and formulate an hypothesis as to the aetiology of the patient's signs and symptoms. Whether or not a clinical picture has a *de facto* 'nocebo' aetiology is an hypothesis that only the physician can put forth and that needs to be scientifically corroborated by objective diagnostic tests. While strictly speaking, nocebo is the wrong term, it is used here because of its all too common usage in the context of wind-turbine-related adverse health effects. As previously stated, a sound is a palpable (perceivable) phenomenon, therefore the correct term would be psychosomatic or psychogenic, which can only be determined by a physician, not an acoustician.

"COBBLER, STICK TO THY LAST!"

But for the emergence of health complaints from otherwise healthy families who live in the vicinity of IWTs, only occupational exposures (and sporadic residential exposures) would be arenas for the 'infrasound issue.' Neglecting issues directly pertaining to public health, though, is usually a more expensive proposition than neglecting occupational health (although both are intertwined) or sporadic cases of residential exposures. Typical occupational exposures do not usually induce the same pathological conditions in worker's family, nor in their neighbours.

When proper medical histories (including the anamnesis) are taken by qualified professionals, it is not, then, within the purview of acousticians to equate these medical determinations with anecdotal stories. In some court proceedings, attempts have been made to equate medical complaints of families living in infrasound-contaminated homes with UFO abduction stories. This is where medical diagnostic tests become relevant, as they can corroborate or negate patient complaints; but it is not the acoustician who is trained to prescribe or interpret them.

The expression used to title this section represents a recommendation offered herein to acousticians. While they can be greatly knowledgeable on the particulars of their instrumentation and the electronic capture of the acoustic signal, it is not their responsibility (nor indeed their business) to opine on the possibility of health effects caused by a particular acoustic environment. Working within deontological correctness, those sorts of questions should be deferred to (knowledgeable) medical healthcare professionals. A variant expression of this title in the English language is “To the cobbler his last, to the weaver his loom.”

In the defence of acousticians, they are expert professionals who must determine whether or not the numerical evaluation of the acoustic environment complies with the numerical permissible exposure levels as stipulated by legislative bodies. This usually entails detailed knowledge of instrumentation and a deep understanding of measurement procedures. Oftentimes, however, the acoustician may be asked to provide numerical values that *are not* part of the mandatory and regulated parameters. They may, therefore, also provide numerical values of the infrasound levels. In this case, acousticians may present these infrasound values expressed with the dBA metric (as many of the less scientifically-minded acousticians often do), thus perpetuating the bias of “what you can’t hear won’t hurt you.” From a biological and public health standpoint, the potential agent of disease is not being quantified; therefore the data is useless for establishing or negating the existence of a particular infrasound level (Fig 2).

CONCLUSION

Many acousticians a) defend the principle that ‘what you can’t hear won’t hurt you,’ b) equate patient complaints with anecdotal information, and c) attribute a ‘nocebo’ aetiology to patients’ symptoms. These positions are (usually) beyond the purview of acoustician training. More importantly, acousticians have no deontological obligation to defend the patient.

Consequently, the opinions of acousticians regarding the possibility of the development of adverse health effects among families living in the vicinity of IWT developments can, and should be, deemed irrelevant in court proceedings. *Sutor, ne ultra crepidam.*

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Disclaimer

The authors 1) do not harbour anti-technology sentiments, 2) consider industrial activities to be important to modern technological societies, 3) have presented this report under one and only one agenda — pure scientific inquiry, and 4) are not producing a report arguing against industrial wind turbine developments.

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