Dr Geoff Leventhall MSc PhD FInstP HonFIOA
Consultant in Noise Vibration and Acoustics

150 Craddocks Avenue Ashtead
Surrey KT21 1NL UK
Tel/Fax: 01372 272 682
e-mail: geoff@activenoise.co.uk

17 November 2012

Dr Ian Holland
Committee Secretary
Renewable Energy (Electricity) Amendment
(Excessive Noise from Wind Farms) Bill 2012.

Dear Dr Holland

1. Thank you for giving me the opportunity to comment on Dr Laurie's submission. My Australian colleagues have been urging me to respond to the way in which she uses/misuses my work, but I have held off from this, as I see no point in getting into a "he said-she said" type of dialogue with her. She is so focussed in her beliefs that she is a person who only believes what she wishes to believe and will either reject new information or bend it to support existing beliefs. When she started off a few years ago, she said that she wished to become the Australian Nina Pierpont, and has certainly succeeded in this.

2. I find it unwise to believe much of what Dr Laurie states, unless there is confirming evidence. She also misuses references, so that you have to be careful to check whether these are relevant and actually say what she claims they do. For example, page 4 in her submission contains serious allegation of widespread dishonesty on the part of the wind industry and others, but there is no back-up confirmation. She really ought to be pinned down to provide the real evidence, if any, of multiple occurrences. It is not uncommon for a noise consultant to arrive at a location to be greeted by a rather grumpy complainant with "You should have come yesterday. It was a lot worse then".

3. On Page 5 she takes one of her frequent digs at me with:

   Over time, the health of those affected relentlessly deteriorates, in a manner which was predictable given peer reviewed, published, acoustical and health research data, available in 2003, about the adverse health effects of low frequency noise on human health. This information was not included in the National Health and Medical Research Council's Public Statement or Rapid Review, despite one of the two reviewers of that Rapid Review being the author of the 2003 document. Nor, it appears, was his conflict of interest of his work with the wind industry disclosed to the NHMRC.

4. I was the author of the 2003 report, reference 7 of Dr Laurie's submission. LFN and infrasound from wind turbines were not considered in the report as they were not believed to be a problem. A belief which I still hold. These sounds did not come to objector prominence until after Dr Pierpont used them in her campaign in about 2005, when wind turbines were proposed for installation in her home area of Malone, NY.

5. No evidence has been produced to contradict the statement in the Rapid Review that "there are no direct pathological effects from wind farms". A direct pathological effect is one which will also be produced in those exposed who could neither see (blind) nor hear (deaf) the wind farms. Work with deaf people shows that they are not influenced by infrasound which they cannot hear. (Landström and Byström 1984, Landström 1987). This work showed that infrasound just below the hearing threshold had no effect on either hearing or deaf people. That which was just above the normal threshold made hearing people sleepy but had no effect on deaf people. People were not affected by sound which they could not hear.

6. There is recent confirmation in the work of Dommes et al, who used functional magnetic resonance imaging fMRI to investigate brain activity of subjects listening to infrasound and low frequency sound. (Dommes, Bauknecht et al. 2009) It was shown that infrasound above the threshold level i.e. which was audible, activated the auditory cortex, which is the part of the brain associated with hearing. Infrasound below the threshold level i.e. inaudible, did not excite the auditory cortex.

7. Some extracts from Dommes et al, with emphasis added, are

   "In our study, no other cortical regions owed a comparably extensive response to the high-level stimuli as did the auditory cortex, indicating that LFT [low frequency tones] were ***mainly perceived via acoustic pathways instead of representing a somatosensory phenomenon.****"*

   "In our study, cortical activation patterns appeared to be similar for all frequencies applied, suggesting that ***LFT are processed in a similar way as frequencies of***

our main hearing range (200 to 5000Hz)."

"We presented the 12Hz stimuli at three different levels. ***Tone bursts of 120 and 110 dB resulted in cortical activation. The 90dB stimulus did not induce a significant response of the auditory cortex*** *in group analysis which, in agreement with the findings of Møller and Pedersen (2004),* ***indicates that this SPL is below the estimated perception threshold for 12 Hz."***

What these quotations mean is that Dommes et al showed that low frequency tones and infrasound are perceived through the normal auditory pathways, the same pathway that is used at higher frequencies. Furthermore, sounds, including infrasound, which are below the hearing threshold, do not produce a response in the brain, as is also the case for higher frequencies at levels below threshold.
This is reinforced by Hensel et al who investigated the transmission of infrasound into the cochlea and stated (Hensel, Scholz et al. 2007)

> *No signs of an abrupt change in transmission into the cochlea were found between infra- and low-frequency sounds.*

In contrast to the unproven claims made by Professor Salt, my own belief continues to be that infrasound from wind turbines is just another sound, which you hear if it is above your hearing threshold and you don't hear if it is below. There is no mystery about infrasound, but it has been falsely used by those opposed to wind turbines in order to alarm others, and also as a distraction, which they know will be difficult and time consuming to work on, whilst at the same time they ask for a moratorium on further constructions until the work is done.

8. I assumed that the NHMRC asked me to look at their Rapid Review because of my standing as an expert in the field, and I responded accordingly. As a Rapid Review, the report cannot be expected to be wide ranging and comprehensive, but has to concentrate on the main points. There was no conflict of interest.

9. Dr Laurie misunderstands my 2003 Defra review. It concentrates on low frequency noise because that is what Defra asked me to write about, but most of what is in it is equally applicable to higher frequency noise. There is not a lot of difference in the annoyance between low frequency and higher frequency noise, although control of low level low frequency noise was hampered by assessment of environmental noise by the A-weighting. As a result, low frequency noise problems were left to

aggravate, whilst higher frequency problems were dealt with quickly, thus giving low frequency noise a relatively bad name. It is also more difficult to determine the direction of low frequency noises than it is for higher frequency noises.

10. A problem which arises from people coming new to the study of low frequency noise, especially with wind turbines as the noise source, is that they do not know what has occurred in the past. Nearly every low frequency environmental noise problem has been caused by **audible** tones, and all the earlier publications relate to annoyance by low frequency tones. Laboratory investigations have been for tones. The German Standard DIN 45680:1997 is designed for tones which exceed the hearing threshold. Tones are typically produced by rotating or reciprocating machinery. To quote WHO Community Noise (Berglund, Lindvall et al. 2000)

    Various industrial sources emit continuous low-frequency noise (compressors, pumps, diesel engines, fans, public works); and large aircraft, heavy-duty vehicles and railway traffic produce intermittent low-frequency noise. Low-frequency noise may also produce vibrations and rattles as secondary effects. Health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general. (Section 3.9)

11. This quote from the WHO is referring largely to tones (components). Throughout the WHO document, it is low frequency **components** which are referred to. The prevalence of tonal problems is shown by Vercammen (Vercammen 2007). The Kokomo Hum is also of interest as a study of tonal problems (Cowan 2003). A tone concentrates the acoustic energy at one frequency, which is more annoying than a spread of energy. A spread of low frequency noise at a low level, such as is produced by wind turbines has not been considered a problem. If a tone and a spread of noise over a band have the same dBA level, then all the components in the band of noise are of lower level than that of the single tone.

12. Exposure to the low levels of infrasound from wind turbines has not been established as a health problem. We have evolved in the presence of natural infrasound and have been exposed for many years to infrasound of human origin Wind turbine infrasound levels are low, typically about 60dB at 10Hz at residences, whilst most wind turbine spectra follow a similar shape. An example is in Fig 1, from " Noise: Windfarms " by Daniel Shepherd. (To be published). The spectrum shows very low

infrasound levels, about 50dB at 10Hz. There is no evidence that this is harmful. Note that the hearing threshold at 10Hz is nearly 100dB.

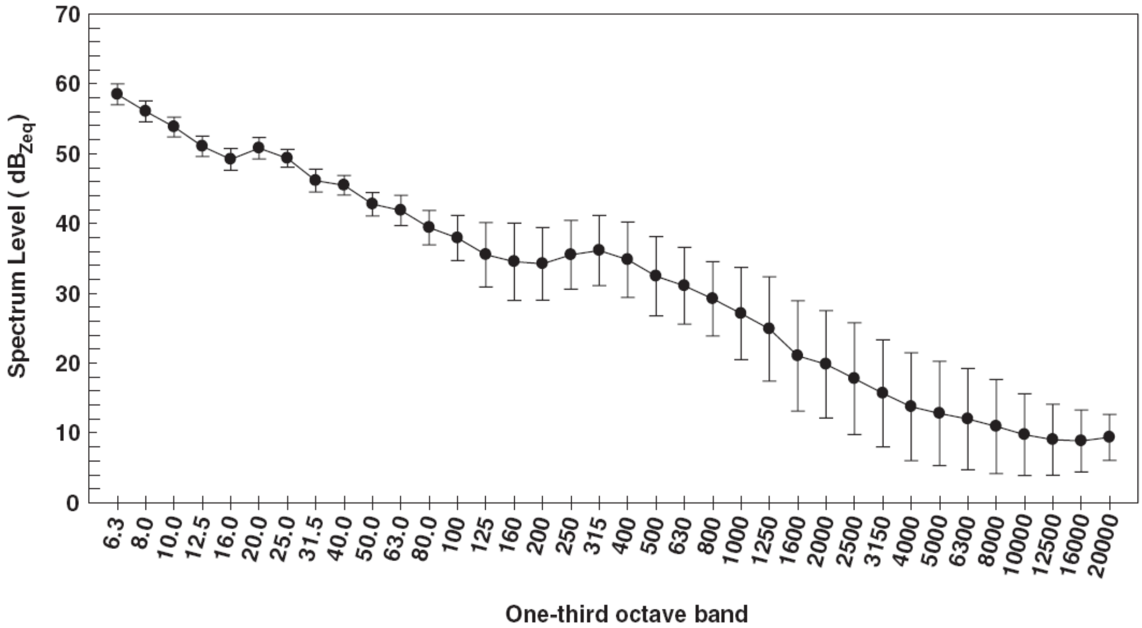

Fig 1 Spectrum of wind turbine sound (after Shepherd). Distance not given

13. Dr Laurie falls into the error of believing that all low frequency noises are the same, which they are not. The noises in the work referred to by Laurie (Mirowska and Mroz 2000) originated from fans, central heating pumps, refrigerators and transformers in buildings. These sources are rich in tones. A tonal source is more annoying than a wide band of noise, and it is to be expected that the subjects used by Mirowska and Mroz would experience more effects.

14. Selection and high-lighting of this study by Dr Laurie is blatant cherry-picking. The paper was a conference paper by Mirowska and Mroz, and not peer reviewed. The chapter in my Defra report, from which the description of this work has been extracted by her, is titled "Surveys of Occurrence and Effects" and describes international work. The paragraph in the Defra report which follows immediately after the description of the Mirowska and Mroz conference paper is

Other work has investigated a group of 279 persons exposed to noise from heat pump and ventilation installations in their homes (Persson-Waye and Rylander, 2001). The experimental groups were 108 persons exposed to low frequency noise and 171 non-exposed controls. There was no significant difference in medical or psycho-social symptoms between the groups.

Dr Laurie chose to ignore this second work, which was a peer reviewed publication in a high quality journal and which gives contrary results to Mirowska and Mroz. As stated earlier, Laurie believes what she wishes to believe, and then tries to give it a gloss of scientific credibility, but frequent repetition of an incorrect fact does not make it correct, although more people may come to believe it. Repetition is an essential part of persuasion in both advertising and propaganda.

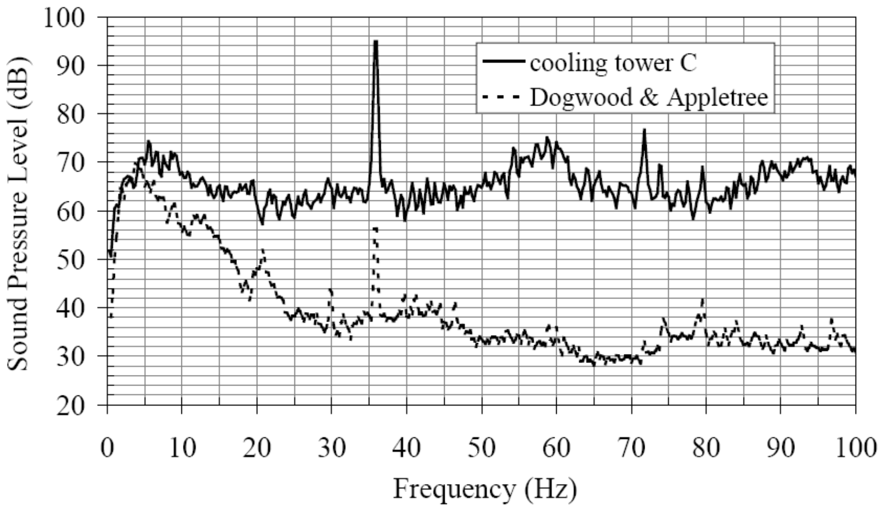

Fig 2a A narrow band spectrum from a large industrial fan

15. Wind turbines produce a band of continuous low level noise, falling at about 5dB/octave as the frequency increases, as shown in Fig 1, which is typical of wind turbine noise measurements. Work on air-conditioning noise has shown this to be a bland and unobtrusive spectrum. (Blazier 1997).The results of investigations of tonal noises cannot be transferred to wide band wind turbine noise. Dr Laurie is incorrect to do this. The variety of low frequency noises is illustrated in Figs 1 and 2. Fig 2a shows a tonal spectrum from a cooling tower fan (Cowan 2003), with a prominent tone at about 36Hz. Fig 2b is a gas turbine spectrum (Hessler 2004), which has prominent spectral components at 16Hz, 31Hz, 125Hz and 4kHz These differ from the wind turbine spectrum of Fig 1, which falls regularly at about 5dB/octave. The

different characteristics lead to different perception and responses. Fig 2a represents a tonal humming sound. Fig 2b is a rumbling sound. Experience in air conditioning shows that Fig 1 is a bland and unobtrusive sound (Blazier 1997) which is not audible at frequencies below about 40Hz, as is typical of wind turbines at residential locations. It is the higher frequencies which are audible and which people respond to, not the low frequency and infrasound.

16. Dr Laurie displays a very poor understanding of the importance of sound levels and does not understand the significance of frequency in relation to level. Decibel for decibel, low frequencies are less harmful than high frequencies.

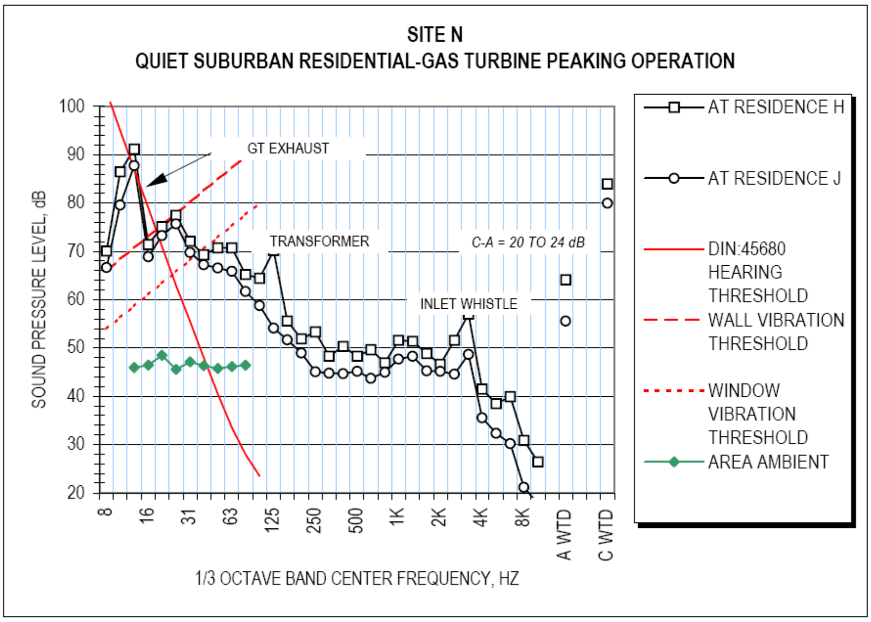

Fig 2b A gas turbine spectrum - electricity generation

17. Dr Laurie is also unable to distinguish between noise and vibration. A further quotation from her submission is (page 5)

The combination of predictable symptoms and health problems related to vestibular dysfunction, chronic sleep deprivation, and chronic physiological and psychological stress, causes relentlessly deteriorating health, in ways which themselves are well known to well established and long standing peer reviewed published clinical medicine. They include a range of serious mental and physical health problems, including cardiovascular diseases and mental health disorders, which can be fatal. There is also a growing body of peer reviewed published scientific research data that there is long term tissue damage from exposure to infrasound and low frequency noise and vibration, which also includes congenital abnormalities.

This information is not new to some – for example a report by military aviation medical researchers in the US recommended that pregnant US military helicopter personnel should be banned from flying certain rotary bladed helicopters known to emit vibration as a result of research done in 1994. The ban is still in place today.

18. Vestibular dysfunction from inaudible infrasound is one of Dr Pierpont's false assertions, based on misinterpretation of other people's work on vibration transmission from the mastoid bone to the inner ear (Todd, Rosengren et al. 2008) . Pierpont switched round noise and vibration to the extent that the author of the work she was misusing publicly rebuked her (Todd 2009). Dr Laurie is slavishly following the errors of her mentor.

19. The use of words like "a growing body of peer reviewed published scientific research data" without referencing any of this data is a sure warning sign that the facts are being stretched.

20. The second paragraph quoted above is irrelevant to wind turbines, which do not vibrate people. Helicopters create a great deal of cabin vibration, which is transmitted to passengers through the seat. It is clearly inadvisable for pregnant persons to be exposed to this. The paragraph is an example of how Dr Laurie uses correct, but irrelevant, science to put a gloss of scientific authority on her flawed statements on wind turbines.

21. It is clear that I have a rather low opinion of Dr Laurie's work. Whilst I criticise those who distort and cherry pick their facts, I do, of course, believe that people can be disturbed and annoyed by noise. I have spent much of the past 40 years helping those affected by noise, including low frequency noises. This work has revealed to me the crucial link between a person's attitude to a noise source and their reaction to the noise. (Leventhall , Robertson et al. 2012) . Attitude to the noise and its source is especially important for low level noises, such as from wind turbines at residences. An audible noise is not necessarily an annoying noise, unless you are antagonistic to the source, when even the lowest level of audibility will create an adverse response.

22. I have been very disturbed at the outbursts against wind turbines coming from objector web pages and the invitations on some to send in health problems to add to the list. This creates fear in those living in the area of projected turbines and a self-search for symptoms in those near operating turbines – every ache or pain is attributed to the turbines and magnified by resentment. These responses demonstrate the operation of a nocebo effect which, in susceptible people will cause stress and consequent effects on health. You cannot become free of a noise problem if you concentrate your attention on it, but you make it worse by this.

23. The fact that our work with a psychotherapist has helped complainants to desensitise from noise and improve their sleep and health shows a relation between attitude to the noise source and its effects (Leventhall, Robertson et al. 2012).

24. To give another example of Dr Laurie's acoustic inadequacy, in her page 11 – Rational for these Demands, it is stated

    Knowledge of the damage to health from exposure to infrasound [8] and low frequency noise [9] (ILFN) has been known for many years.

    Reference 9 is my 2003 Defra report, reference 8 is

    NIEHS (National Institute of Environmental Health Sciences)
    November 2001, "Infrasound Brief Review of Toxicological Literature"

    However, the NIEHS review is entirely focussed on exposures to very high levels of infrasound. I am genuinely appalled that Dr Laurie believes that experimental exposure to high levels of Infrasound, around 125dB and higher, is relevant to the low levels of infrasound from wind turbines, although this gross misunderstanding might explain some of her irrelevant and inaccurate statements. It surprises me that a former medic, who must have prescribed many doses of safe medication, cannot grasp the concept of safe doses of noise. An exposure to 120dB is one million times the intensity at 60dB, which is the infrasound level typical of wind turbines at 10Hz at residences. It is so important to understand this difference that I have reproduced the Executive Summary of the NIEHS report as my Appendix 1. In this, I have highlighted the levels used in the experiments reviewed in the report. None of it is relevant to wind turbines. Dr Laurie clearly has very little understanding of acoustics or decibels and should not comment in these areas.

25. A bit about me. My work has been both as an academic and consultant. I have worked on low frequency noise and infrasound since the late 1960s. Since the mid 1980s I have been drawn into the wind turbine infrasound/LFN area and have ended up partly as a debunker of some of the strange claims which are made about infrasound. Although this may not be my preferred role, it has become a very necessary one (Leventhall 2006).

Dr Geoff Leventhall

APPENDIX 1 Executuve summary of Laurie Reference 8
Infrasound Toxicological Summary November 2001

Executive Summary

Infrasound is acoustic energy with frequencies up to 20 Hertz (Hz), having wavelengths of 17 m or more. Some definitions give the upper limit of 16 Hz; others restrict infrasound to delivery by air transmission. Infrasound is seldom generated at high sound pressure levels (SPL; usually measured in decibels [dB]) without accompanying audible sound (1). However, hearing protection, e.g. ear muffs and ear plugs, offers little protection against infrasound exposure (2,3).

Infrasound exposure is ubiquitous in modern life. Infrasound is generated by natural sources such as earthquakes (4) and wind; means of transportation such as automobiles, trucks, aircraft, watercraft, and rail traffic (4-6); certain therapeutic devices (which do not meet the restriction of infrasound to airborne delivery) (7-16); numerous industrial sources such as heavy machinery and air compressors; air heating and cooling equipment; and household appliances such as washing machines (1,5,6,17). The potential use in nonlethal acoustic weapons is discussed briefly (18-20). OSHA guidelines for occupational noise exposure are concerned with SPL limits (90 to 115 dB(A) for 8 hours to 0.25 hour), not frequencies (21). The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that except for impulsive sound with durations of less than 2 seconds, one-third octave levels for frequencies between 1 and 80 Hz should not exceed a SPL ceiling limit of 145 dB, and the overall unweighted SPL should not exceed a SPL ceiling limit of 150 dB; no time limits are specified for these recommended levels (22).

NASA criteria for noise exposure in space craft and space stations include a limit of 120 dB for 24-hour exposure to 1 to 16 Hz (23).

Literature retrievals from several biomedical databases, the National Technical Information Service (NTIS) file, and the Internet required the inclusion of the words infrasound or infrasonic. The presentation of the information in the toxicology section is in the style of an annotated bibliography. The human studies subsection is not comprehensive and includes only selected studies identified in the open literature. All of the 59 animal toxicity studies identified in the literature searches are included, but the subsection is not totally comprehensive. A few additional publications were cited in some of the references. A large fraction of the annotations are based on the authors' abstracts in the database records. Annotations for many of the Russian studies were based on limited data extraction from the original [non-English] articles since the database records frequently did not have abstracts.

Summary of Studies in Humans

The literature search identified 69 studies, 34 of which are in English. The records for about half of the foreignlanguage publications do not have abstracts. Altogether, only two-thirds of the records have abstracts. Twenty-four of the identified human studies are included in the annotated bibliography. Of these, references for 6 citations have been retrieved. English abstracts are available for 15 citations. The effects studied were on the cardiovascular (the myocardium) and nervous systems, eye structure, hearing and vestibular function, and endocrine modulation.

Specific CNS effects studied included annoyance, sleep and wakefulness, perception, evoked potentials, electroencephalographic changes, and cognition.

The primary effect of infrasound in humans appears to be annoyance (24-26). To achieve a given amount of annoyance, low frequencies were found to require greater sound pressure than with higher frequencies; small changesin sound pressure could then possibly cause significantly large changes in annoyance in the infrasonic region (24). Beginning at 127 to 133 dB, pressure sensation is experienced in the middle ear (26). Regarding potential hearing damage, Johnson (27) concluded that short periods of continuous exposures to infrasound below 150 dB are safe and that continuous exposures up to 24 hours are safe if the levels are below 118 dB.

There is no agreement about the biological activity of infrasound. Reported effects include those on the inner ear, vertigo, imbalance, etc.; intolerable sensations, incapacitation, disorientation, nausea, vomiting, and bowel spasm; and resonances in inner organs, such as the heart.

Infrasound has been observed to affect the pattern of sleep minutely. Exposures to 6 and 16 Hz at levels 10 dB above the auditory threshold have been associated with a reduction in wakefulness (28). Workers exposed to simulated industrial infrasound of 5 and 10 Hz and levels of 100 and 135 dB for 15 minutes reported feelings of fatigue, apathy, and depression, pressure in the ears, loss of concentration, drowsiness, and vibration of internal organs. In addition, effects were found in the central nervous, cardiovascular, and respiratory systems (29). In contrast, a study of drivers of long distance transport trucks exposed to infrasound at about 115 dBA found no statistically significant incidence of such symptoms (e.g., fatigue, subdued sensation, abdominal symptoms, and hypertension) (30).

Studies have shown that infrasound (6 to 16 Hz at levels ranging from 95 to 130 dB and up to an exposure time of one hour) causes an increase in diastolic blood pressure and decreases in systolic blood pressure and pulse rate (31). Long-term exposure of active Swiss airforce pilots to infrasound with a frequency of 14 or 16 Hz at 125 dB produced the same changes. Additional findings in the pilots were decreased alertness, faster decrease in the electrical resistance of the skin compared to unexposed individuals, and alteration of hearing threshold and time perception (32). However, a whole-body exposure to infrasound at 10 and 15 Hz (level not provided) did not produce changes in respiration, pulse, and blood pressure (33).

In several experiments to assess cognitive performance during exposure to infrasound (7-Hz tones at 125, 132, and 142 dB plus ambient noise or a low-frequency background noise for up to 30 minutes), no reduction in performance was observed in the subjects (34). Sole exposure to infrasound at 10 to 15 Hz and 130 to 135 dB for 30 minutes also did not produce changes in autonomic nervous functions (35). The ability of infrasound (5 and 16 Hz at 95 dB for five minutes) to alter body sway responses suggested effects on inner ear function and balance (36).

Summary of Studies in Laboratory Animals: Acute Exposure Duration

Citations for 31 acute animal studies are annotated in this section; 9 of the references have been retrieved and are available in English. English abstracts are available for an additional 5 references.

Studies of infrasound up to 124 dB for up to four hours found transient effects in behavior, brain chemistry, and effects on blood vessels. Studies at higher SPL induced cochlear damage and other morphological damage in the ear. Thus, rats exposed briefly to infrasound around 120 dB showed changes in concentrations of acetylcholine (37), acetylcholinesterase, brain glutamate (increases) (38), and brain norepinephrine and dopamine (decreases) (39,40). Gastric mucosal blood flow decreased (41) and organ tissue permeability increased (42). At about 100 dB, rats showed reduced endurance in already poor treadmill performers (43), performance decrements in acquisition and retention of conditioned reflexes, and somnolence (44). Acute exposure of mice to ethanol plus infrasound reduced time to submersion in forced swimming tests (45-47). A one-hour exposure to 20 Hz at up to 133 dB SPL did not induce the cochlear and hair cell damage observed in guinea pigs that had been exposed to 163 dB SPL. No morphological changes were observed up to 140 dB (48,49). Infrasound exposure induced endolymph displacement, altered the endonuclear potential (50,51), and reduced the amplitude of the auditory evoked potential and prolonged its latency time in guinea pigs (52). Continuous or intermittent infrasound exposure of chinchillas at 150 to 170 dB induced considerable damage in the ear, including tympanic membrane perforation, bleeding, hair cell damage, saccular wall rupture, Reissner's membrane rupture, and endolymphatic hydrops (53). Continuous exposure was responsible for most of the incidences of several of these endpoints. Too few data were included about rabbit and monkey experiments for summarization.

Summary of Studies in Laboratory Animals: Short-Term Exposure Duration

Twenty short-term studies have been annotated. Full articles in English are available for 8 of the references. Abstracts in English are available for 11 additional citations.

In the short-term animal studies with exposures up to 145 Hz for up to four months, adverse effects were noted on the morphology, histopathology, and histochemistry of the cardiovascular system, nervous system, the ears, the liver, and other organs.

Rats exposed to 8 Hz at 120 dB for up to 45 days showed myocardial cell pathology, microcirculation disturbances, ischemia, and mitochondrial destruction in capillaries (54). Rats exposed to 10 to 15 Hz at 135 to 145 dB for 45 days showed arterial constriction, nuclear deformation, and mitochondrial damage. Regeneration occurred after exposure stopped (55). Rats exposed to 8 or 16 Hz at 120 to 140 dB for up to 40 days showed reduced oxidationreduction (redox) enzymes in the myocardium, disturbed blood flow, myofibrillar fragmentation, and RNA and DNA changes. Regeneration began within 40 days after infrasound exposure ceased (54,56). Exposure of rats to 8Hz at 115 and 135 dB for four months induced morphological changes in the myocardial ultrastructure; significant decreases in succinate dehydrogenase and myocardial adenosine triphosphate (ATP) and adenosine diphosphate (ADP); and significant increases in 〈-ketoglutarate dehydrogenase, myocardial adenosine monophosphate (AMP), and plasma corticosterone (57).

Rats exposed to 8 Hz at 100 dB for up to 60 days showed biochemical and morphological changes in blood and tissues, including dystrophic tissue changes in the lungs, liver, kidneys, heart, adrenals, and testicles. Imidazole treatment reduced the dystrophic tissue changes and changes in enzyme concentrations (58). In studies of infrasound-induced histopathological and morphological changes in the liver after 40-day exposures, the most damage was observed at 8 and 16 Hz at 140 dB. Damage included strongly deformed nuclei, lysis and vacuole formation in the cytoplasm, and lipid granules in the cytoplasm (59). Exposure of rats to 8 Hz at up to 140 dB for 25 to 45 days caused irreversible changes in hepatocytes (60). Exposures of 8 and 16 Hz at up to 140 dB for up to 35 days induced fluctuations in heart and liver enzyme levels.

Exposure of rats to 8 Hz at 110 dB for ten weeks induced transient changes in working capacity and oxygen requirements, increased unconditioned reflexes, and induced immunological effects (61). Exposures to 8 Hz at 120 and 140 dB for up to 40 days induced changes in the heart, neurons, and auditory cortex that increased in severity with length of exposure (62). Exposures to 8 Hz at 100 and 140 dB for up to 25 days affected conjunctival blood vessels. Capillaries initially constricted and an increased permeability of blood vessels led to capillary and tissue swelling (63). Exposure to 4 Hz at 110 dB for 40 days induced ear damage worse than that observed after exposure to 31.5 or 53 Hz at 110 dB for 40 days. Alkaline phosphatase activity was reduced in the blood vessels of the stria vascularis and their permeability was impaired. The infrasound exposure induced neurosensory hearing impairment (64).

Mice exposed to 8 Hz at 120 dB showed erythrocyte-filled acini and thickening of the inter-alveolar septa of the lungs. Exposures of 8 and 16 Hz at 140 dB ruptured blood vessel walls and destroyed acini (65).

Guinea pig short-term studies reported ear damage. Exposure to 4 Hz at 110 dB for 40 days increased alkaline phosphatase concentrations in vessels of tympanic membranes (66). Exposures to 8 or 16 Hz at 90 to 120 dB for up to 25 days induced morphological changes in receptor cells and hair cells of the inner ear. These changes and changes in the endoplasmic reticulum and mitochondria recovered after exposure ended (67).

Rabbits exposed to 10 Hz at 100 to 110 dB for 24 days showed disturbances of enzyme levels of the mitochondria and reduced contractile function of the myocardium (68).

Summary of Other Animal Studies

Synergistic and antagonistic effects were reported in several of the acute and short-term animal studies. Two articles and 3 abstracts are available in English. Diazepam (39), ethanol (46,47,69), imidazole compounds (58), ascorbic acid (69), and microwave radiation (61) moderated the adverse effects of infrasound exposure.

Nine citations covering reproductive and developmental effects, carcinogenicity, genotoxicity, immunotoxicity, and other studies were considered for this report. English abstracts are available for 3 of these studies.

The only finding relating to reproductive effects was dystrophic changes in rat testicles (58).

No studies were identified on subchronic and chronic toxicity, carcinogenicity, anti-carcinogenicity, and initiation/promotion of cancer. Details for a study of genotoxicity in rat bone marrow cells have not been reviewed.

Infrasound pretreatment (10 Hz, 155-160 dB) made guinea pigs less sensitive to antigen induction of anaphylactic shock (70). Infrasound exposure of rats and rabbits to 8 Hz at 115 dB enhanced the immunotoxic effects of gamma radiation on cell and humoral immunity and on autoimmune processes (71).

In an *in vitro* study, ATPase activity in rat whole blood decreased at 16 Hz at 120 dB but increased at 2 Hz. Superoxide dismutase (SOD) concentrations increased with increasing frequency (72).

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