Alberta Utilities Commission
Proceeding 29377
Oyen Wind Power Project

Impacts of Infrasound Frequencies and Vibrations from the Proposed Wind Turbines

By

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Prepared for:
Ackroyd LLP
(Counsel to the Oyen Landowners Group)

INTRODUCTION

I have been retained by Ackroyd LLP to provide an opinion regarding the impacts of infrasound frequencies and vibrations from the proposed wind turbines. I was also requested to review and provide my comments on the *Wind Turbine Noise and Health Study: Summary of Results* prepared by Health Canada as well as Appendix B *(Infrasound and Wind Turbine Projects*) and Appendix C (*Literature Review on Potential Effects on Livestock and Mammalian Wildlife*) in the expert report of Christopher A. Ollson, Ph.D., which I understand was prepared for the Alberta Utilities Commission in another proceedings (the Fox Meadows Wind Project, Proceeding 29266).

I specialize in general practice and emergency medicine, with a focus on cardiovascular diseases, microcirculation and endothelial functions, vascular biology and stress medicine. I work internationally as an emergency doctor in hospitals and on ships. Since about 2004, I have also been doing scientific work in the field of microcirculation, endothelial functions and vascular biology. In 2022, the first publication for *Springer Nature* appeared in the *essentials* book series. It summarises the current state of scientific knowledge in the field of microcirculation and endothelial functions in a concise form. The state of knowledge since 2000 reflects a significant advance in our understanding of the vital regulations of endothelial cells and the importance of laminar forces in the capillary network that control these functions. I am also a nature conservationist. My CV is provided with this expert report.

I acknowledge that I have a duty to give an independent opinion on issues within my expertise and experience in a manner that is fair, objective and non-partisan.

PART 1: IMPACTS OF INFRASOUND AND VIBRATIONS

a) *Properties of Low-Frequency Sound*

The properties of low-frequency sound must first be considered. Sound, infrasound and ultrasound propagate as longitudinal waves in *all viscoelastic materials* (i.e., the pressure changes oscillate in the direction of propagation). It is an *energy transfer*.

Audible sound is in the range from about *20 hertz (Hz) to 20 kilohertz (kHz), infrasound* is below *20 Hz* and *ultrasound* above *20 kHz*.
The kinetic energy of the wind that acts on the turbine, is partly converted into electricity and partly into heat, audible sound and infrasound. The latter is not acoustically perceptible, but as a physical force encounter animate and inanimate matter upwind and downwind. It can be reflected, but can also penetrate all viscous elastic materials and come into conflict with animate and inanimate matter.

Sound differs physically in frequency and thus in wavelength. The wavelength (L) is in relation to the frequency (f) and to the speed of sound (V) in the respective medium. In general, the lower the frequency, the greater the wavelength, the lower the damping, the greater the flexural capacity of the sound. For example, sound propagation in air with a wavelength of 0,1 Hz is around *3,4 km*, that of 1000 Hz is around 34 mm.

Infrasound is much less attenuated by propagation through the atmosphere as well as through roofs and walls than the *audio spectrum*. Infrasound propagates in all viscoelastic mediums; therefore, it also propagates in organisms. Infrasound can induce low-frequency vibrations in all bodies such as organism and buildings. The sound differs in frequency, sound pressure, time/effect profile (impulsiveness) and temporal occurrence, which is crucial for its *information* and the organism's ability to compensate and to recover[1].

Information is created by the interaction of *all the components of a sound* in organism. Persinger, 2014. in the paper: *Infrasound, human health, and adaptation: an integrative overview of recondite hazards in a complex environment* at page 503 stated as follows: "*Pure sine waves or simple time-varying patterns are found less frequently in the environment than complex acoustic and electromagnetic patterns that have the potential to mediate information between the environment and cells at very low levels of intensities. Relying on only the average intensity overtime for these sources (such as infrasound) as indicators of their importance is about as useful as only measuring the loudness of a conversation to discern its syntactic content and meaning* ".
A conscious recording is not required for the information of a sound. [2].

[1] Persinger A, *Infrasound, human health, and adaptation: an integrative overview of recondite hazards in a complex environment*. Nat Hazards (2014) 70:501–525. DOI 10.1007/s11069-013-0827-3 [**Persinger, 2014**].

[2] Persinger, 2014; and Weichenberger M, Bauer M, Kühler R, et al. *Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold—evidence from fMRI*. Plos One.

According to Persinger, 2014[3], low frequencies below 10 Hz have a special information content. This can best be explained by the fact that the *conductivity* of crucial organic structures is particularly higher for infrasound; at the same time, it was confirmed that an impulsive stressor (rapid rise at the beginning) is significantly greater than a continuous one[4].

FIG. 1[5]

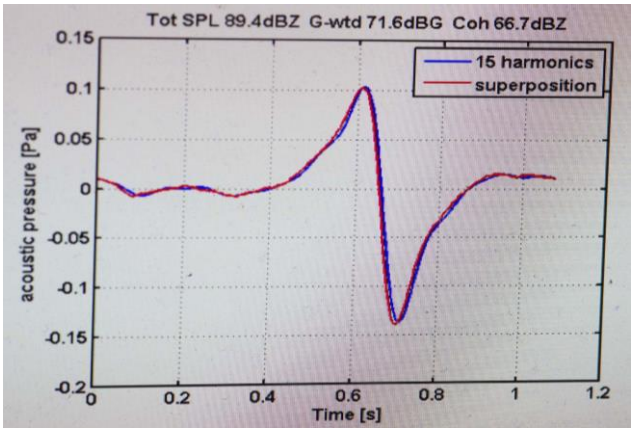


Figure 1 is an infrasonic pulse extracted from the emission of a wind turbine.

The fluctuations of sound pressure measurable near a wind installation usually contain noise, *i.e.,* irregular sound events of different origin. Noise removal is possible by averaging the sound pressure over a large number of mast-blade passages (here 4100), which reveals their common element (red line). The red peak thus visualized from the time sequence coincides with the blue peak, which shows the fundamental pulse as reconstituted in the frequency domain from 15 (very sharp) harmonic lines by Fourier analysis. The result is the coherent fundamental peak of this turbine of 0.9 Hz frequency, accordant to 1.08 seconds required per blade passage. Extracted infrasonic pulse of a wind turbine showing the relation between sound pressure (P) and time (s). Original source corresponding to **Figure 7** in Vanderkooy[1] J, Mann[2], R Measuring Wind Turbine Coherent Infrasound Department of Physics and Astronomy 1, Department of Computer Science 2 University of Waterloo, Waterloo, ON, Canada, N2L3G1 jv@uwaterloo.ca, mannr@uwaterloo.ca Date posted: 2 October, 2014. With permission.

Impulsive repetitive signals such as in FIG. 1 are produced e.g., from wind turbines. The Fourier Transform (Power spectrum) of such a signal consists of multiple harmonics (sine signals) with equal spaced frequencies, starting from the lowest frequency which is the repetition frequency. The higher harmonics are multiples of this basic frequency[6].

2017; 12: e0174420. Available: https://doi.org/10.1371/journal.pone.0174420 [**Weichenberger et. al., 2017**].

[3] Persinger, 2014.

[4] Mazzag, B. and Barakat, A.I. (2010) *The Effect of Noisy Flow on Endothelial Cell Mechanotransduction: A Computational Study*. *Annals of Biomedical Engineering*, 39, 911-921. https://doi.org/10.1007/s10439-010-0181-5; and Mazzag, B., Gouget, C., Hwang, Y. and Barakat, A.I. (2014) Cap. 5. *Mechanical Force Transmission via the Cytoskeleton in Vascular Endothelial*.

[5] Original source is at Vanderkooy et. al., 2014.

[6] Persinger, 2014; and Vanderkooy J, and Mann R. *Measuring Wind Turbine Coherent Infrasound*; Department of Computer Science, University of Waterloo, Waterloo, ON, Canada. Date posted: 2 October, 2014 [**Vanderkooy et. al., 2014**] link: Optimum Measurements of Quasi-periodic Wind Turbines.

In consequence, the information of a sound as it is received by the recipient, consists *of its overall sound* (comparable in music). All qualities such as frequency (Hz), sound level (Pa) or sound pressure level, *SPL* (dB), time/effect profile e.g., impulsivity and temporal appearance can only be assessed in the totality of all qualities, never just by one quality[7]. Remarks: we do not weight variant of a dB scale, like dB(A), dB(C) or dB(G). Please compare FIG. 4 and the accompanying text.

The planned *Oyen project* encompasses a phase 1 with a maximum of 45 turbines for a generation capacity of 250 MW and phase 2 that will include a maximum of 38 turbines for a generation capacity of 216 MW. This results in an average nominal output of one wind turbines of around 5.5 MW for phase 1 and around 5.6 MW for phase 2 per unit.

As a result, in the planned turbines of the Oyen project, the frequencies are at comparable depths with modern turbines, namely values down to 0.25 Hz. The height of the turbine is not the decisive factor for the frequency, but the rotor diameter.

b) *Summary of Position*

My position based on my review of the current body (in the last 5-10 years) of scientific knowledge on the subject is that infrasound from long-term exposure to wind turbines will lead to serious health problems, particularly for residents of residences in the vicinity. Farm and domestic animals that cannot leave the area are also affected. The distance at which serious health disturbances may be avoided is to be determined scientifically and beyond that depends on many other factors. These include e.g., the descending fundamental frequencies due to the increasing size of the rotor diameter, the main wind direction and wind speeds, the interaction of emissions from several wind turbines, the possible interferences between different wind farms, the topography. At the present time, 'sufficient distances' can only be estimated on the basis of the most recent studies (see later) that demonstrate the effects on animal populations and plants at distances of minimum 10 kilometres around a single wind turbine. Before establishing safe distances, various low-frequency forces need to be re-evaluated in terms of their effects before establishing safe distances could occur.

Fundamentally, the work by *Ardem Patapoutian* (which led to the award of the Nobel Prize in Medicine in 2021) classified PIEZO channels as currently the most important group of mechano-sensors, a crucially newly recognized level of perception of *physical forces* and *sound* in all living things[8]. The key difference *is that infrasound is primarily processed outside the ear*, which is why an *auditory perception threshold does not allow the effects of infrasound* to be assessed.

[7] Persinger, 2014.

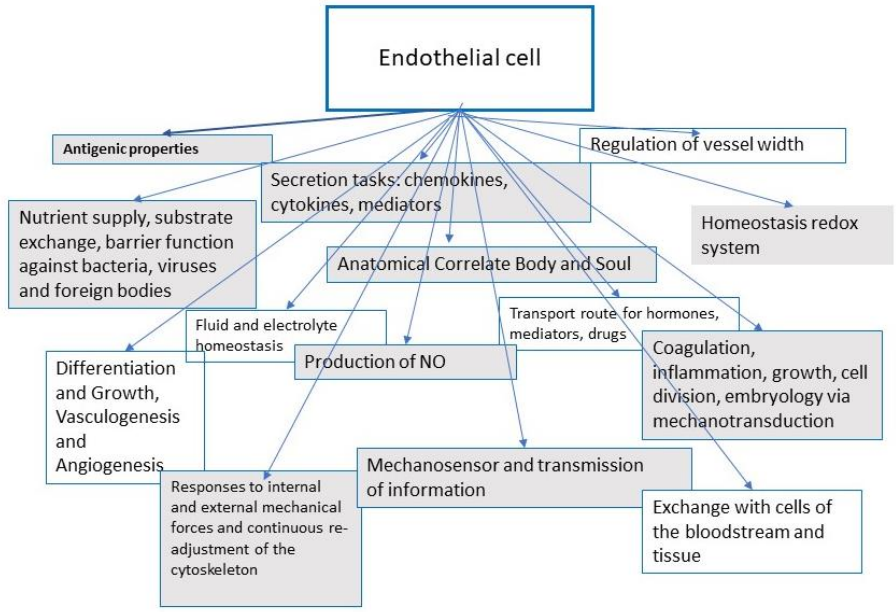
[8] Andolfo I, Alper SL, Iolascon A. *Nobel prize in physiology or medicine 2021, receptors for temperature and touch: Implications for Hematolo*gy. Commentary. 2021. DOI: 10.1002/ajh.26407

All living beings are equipped with corresponding mechano-sensors and also "hear" with the inside of their body. This means that 'hearing' with the ear cannot provide any information about the effects of infrasound. Therefore, studies based on the evaluation of auditory impressions *cannot provide valid insights into the effects of infrasound*.

The second important scientific result as it relates to assessing the impact of infrasound is the finding that endothelial functions (endothelial cells are multipotent cells of the inner wall of all vessels) depend *on laminar, uniform flows* in the capillaries and control vital regulations of endothelial cells via *mechano-sensors*, receptors for *forces and sound*. These include, for example, the *autoregulation of the vascular system* according to current needs, blood pressure regulation, the homeostasis of inflammations, growth, cell division, vasculogenesis and embryogenesis, to name just a few[9].

An overview of the most important *endothelial functions* can be found in **FIG. 2** below[10].

FIG 2.



[9] Fernandes CD, Araujo Thaıs S, Laurindo FRM, Tanaka LY. Cap. 7. *Hemodynamic forces in the endothelium. mechanotransduction to implications on development of atherosclerosis*. In: Da Luz PL, Libby P, Laurindo FRM, Chagas ACP, Eds., *Endothelium and Cardiovascular Diseases. Vascular Biology and Clinical Syndromes*, Mica Haley, Sao Paolo. 2018; 85-94;

- Bellut-Staeck UM. *Die Mikrozirkulation und ihre Bedeutung für alles Leben. Untertitel: Aktuelle Erkenntnisse zu lebenswichtigen Funktionen von Endothelzellen*. In Series Titels: Essentials. Publisher Springer Berlin, Heidelberg; 2022. Available: https://doi.org/10.1007/978-3-662-66516-9.Softcover ISBN978-3-662-66515-2; and

- Bellut-Staeck UM. *Impairment of the endothelium and disorder of microcirculation in humans and animals exposed to infrasound due to irregular mechano-transduction*: Journal of Biosciences and Medicine. 2023; 11(6) DOI: 10.4236/jbm.2023.116003 [**Bellut-Staeck, 2023**].

[10] Bellut-Staeck, U. (2022). Die Endothelzelle und ihre vielfältigen Aufgaben. In: Die Mikrozirkulation und ihre Bedeutung für alles Leben. *essential*. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-662-66516-9_3

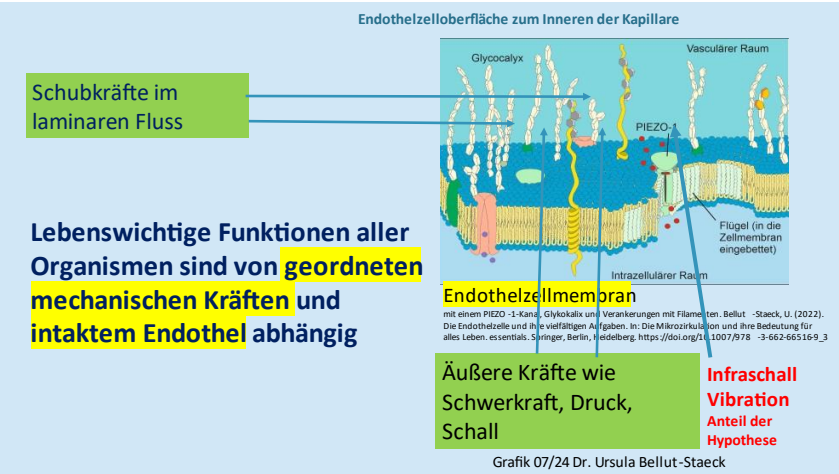
It is scientifically proven that the release of nitric oxide (NO) is triggered by the shear stress reaction of the laminar flow of capillaries. The consequences of inadequate NO release, whereby inadequate means not with the right amount and/or not in the right place and/or not at the right time, lead to chronic deleterious consequences such as, among other things, an increase in oxidative and oscillatory stress. Chronic oxidative and oscillatory stress are the main causes of endothelial transformation of the endothelium into an inflammatory state which, among other things, is the basis for atherosclerosis and all its consequences (high blood pressure, vascular diseases, heart attacks, strokes), but also for the restriction of other important endothelial functions such as embryogenesis.[11].

This means (based on current scientific knowledge) that vascular health and thus human health is closely linked with the preservation of the *integrity of the endothelium* (the sum of all endothelial cells as whole organ). A loss of endothelial integrity means, inter alia, premature ageing, arteriosclerosis, increased blood pressure, lack of energy and loss of homeostasis.

There is strong evidence that a continued periodic impulse with impulsive low frequencies leads to non-demand-driven irregular information at the mechano-sensor level of PIEZO channels (peer-reviewed studies Bellut-Staeck [12,14]).
Continuously increasing oxidative and oscillatory stress, which is the basis for the dysregulation of the autochthonous vascular regulation will lead to an inflammatory transformation of the endothelium with all its consequences[12].

[11] Bellut-Staeck, 2023; Botts SR, Fish JE and Howe KI. *Dysfunctional Vascular Endothelium as a Driver of Atherosclerosis: Emerging Insights into Pathogenesis and Treatment. frontiers in Pharmacology* (2021) Doi: 10.3389/fphar.2021.787541 [**Botts et. al., 2021**]; and Pries AR. *Coronary Microcirculatory Pathophysiology: Can we afford it to remain a black box?* European Heart Journal. 2016; 38:478-488. Available: https://doi.org/10.1093/eurheartj/ehv760.
[12] Botts et. al., 2021.

FIG 3[13].



Based on the current state of scientific knowledge, globally consistent complaints and health disorders from people in the vicinity of wind turbines can be conclusively categorized. Dizziness, headaches, tinnitus, weakness, etc. can be attributed to a disorder of the otherwise autochthonous vascular regulation, which is also referred to as a *microcirculation disorder*. Due to my specialisation, I was able to recognise microcirculation disorders in people living near wind turbines based on their symptoms. Blood pressure increases, cardiovascular diseases, and immune deficiencies can develop or be aggravated in pre-existing conditions.

c) *Summary of Reviewed Studies*

Since 2017, there has been a significant increase in peer-reviewed studies that, on the one hand, consistently show a causal relationship between the infrasound stressor and serious health effects and, on the other hand, provide evidence of the interaction of the infrasound stressor with cellular structures. I have provided a summary of relevant studies below.

The meta-analysis by Dumbrille et al., 2021[14] is the most comprehensive epidemiological study on the health effects of infrasound to establish a causal link between the environmental factor of infrasound emissions and serious health effects, using the generally accepted Bradford-Hill criteria. The *Bradford-Hill* criteria enable the assessment of a possible causal relationship between an environmental cause (e.g., exposure to a toxin) and a suspected effect (e.g., disease) on the basis of *nine* criteria. In medicine, they are used in particular in the field of public health research.

[13] Bellut-Staeck U, *Chronic Infrasound Impact is Suspected of Causing Irregular Information via Endothelial Mechano-transduction and Far-reaching Disturbance of Vascular Regulation in All Organisms*. Chapter 5. Print: ISBN: 978-81-975566-2-3, eBook ISBN: 978-81-975566-5-4. DOI: https://doi.org/10.9734/bpi/mria/v8/727. [**Bellut-Staeck, 2024**]

[14] Dumbrille A, McMurtry RY, Krogh Marie C. *Wind turbines and adverse health effects: Applying bradford hill's criteria for causation*. Environmental Disease. 2021; 6: 65-87. [**Dumbrille et al., 2021**] accessible: Environmental Disease

1. *Strength of the association*, i.e., the size of the risk, as measured by appropriate statistical tests.

2. *Consistency*, i.e., the association is replicated in different settings and using different methods.

3. *Specificity*, i.e., a single specific putative cause produces a specific effect.

4. *Dose-response relationship*, i.e., an increasing amount of exposure to an agent, either in amount or duration, increases the risk of disease.

5. *Temporal relationship*, i.e., exposure to the cause always precedes the effect.

6. *Biological plausibility*, i.e., the relationship accords with currently accepted understanding of pathophysiological processes.

7. *Coherence*, i.e., the association is compatible with current understanding of theory and practice.

8. *Experiment*, i.e., the condition can be prevented or relieved by the regimen of an experiment, e.g., a randomized controlled trial.

9. *Analogy*

The result was that the causality of negative health effects and the stressor could be confirmed *in all* '*Bradford Hill criteria*'. Reported adverse effects on animals revealed not only stress reactions but also negative effects on *fertility, development, and reproduction*. The *Bradford-Hill criterion dose-response*, analyses showed a demonstrable deterioration in *mental performance* from residents, living within 1.4 km of wind turbine(s) to those living outside this radius, increased complaints occurred when the frequencies approached lower frequencies (0.2 Hz in the example mentioned).

In Dumbrille et. al., 2021, the authors concluded as follows:

> *"Incontrovertible proof of causation has tended to be an elusive goal. The debate of determining causality associated with placing IWTs* [industrial wind turbines] *near family homes is similar to past controversies around the debate of causality from the use of tobacco products and from worker exposures to asbestos and coal. The "best available evidence" is the current standard, and it is our contention that the Bradford Hill criteria are that standard.*
>
> *Based on our analysis of clinical, biological, and experimental evidence and its concordance with the nine BH* [Bradford-Hill] *criteria, we conclude that there is a high probability that emissions from IWTs, including infrasound and LFN* [low-frequency noise]*, result in serious harm to health in susceptible individuals living and/or working in their proximity. These effects can be attributed to IWT-related events such as recurring sleep disturbance, anxiety and stress, and likely others.*

With the growing weight of evidence indicating this causation and the rapid proliferation of IWT installations globally, preventative actions should be taken, and policies implemented that are more cautiously protective of public health, safety, and welfare rather than wait for absolute certainty. More stringent regulation is needed to recognize, monitor, analyze, and document effects on the health of local residents and animals. Of concern is the lack of determination of the safe exposure cumulative dose of noise, including LFN and infrasound, for adults, the elderly, and particularly for fetuses and young children.

There are no evidence-based guidelines for setbacks of IWT; rather regulations have a wide variance across jurisdictions. The concern is compounded by the lack of centralized vigilance monitoring for those who have constant, long-term exposure while living in their homes. Our findings provide compelling evidence that there is a pressing need for risk assessment before deployment of IWT into rural community settings that consider more effective and precautionary setback distances. A margin of safety sufficient to prevent pathogenic LFN from being detected by the human vestibular system is paramount before proceeding with political or economic policies."

In my opinion, the study by Dumbrille et al., 2021, which shows a causal link between emissions from wind turbines and negative health effects, should have led to immediate precautions in the development of industrial wind turbines near residential areas.
Further, the study by Krogh et. al.[15] used the *Grounded Theory* to study why some people contemplate vacating or abandoning their homes when living within 10 km of industrial wind turbines. Following their study, the authors concluded as follows: *"Grounded Theory methodology served as a practical tool to lend support for the theory that housing decisions of all 67 participants were motivated by the proximity of a wind energy facility within 10 km of their homes and the participants' observations of the occurrence or potential risk of adverse health effects. Some temporarily left during the day and/or night to alleviate their adverse effects."*[16]

The following two peer-reviewed studies show in a coherent and stringent way the likely pathological pathway by which infrasound leads to interaction with cellular structures of organisms via PIEZO channels[17].

Several international studies have shown that the transmission of *infrasound* is associated with verifiable stress responses of cellular structures. Louisinha et. al., 2018 concluded that infrasound interacts with cell metabolism and leads to perivascular

[15] Krogh, C.M., McMurtry, R.Y., Johnson, W.B., Dumbrille, A., Alves-Pereira, M., Punch, J.L., Hughes, D., Rogers, L., Rand, R.W., James, R., Ambrose, S.E. and Gillis, L. (2021) *Grounded Theory as an Analytical Tool to Explore Housing Decisions Related to Living in the Vicinity of Industrial Wind Turbines*. Open Access Library Journal, 8: e7233. https://doi.org/10.4236/oalib.1107233 [**Krogh et. al., 2021**].
[16] Krogh et. al., 2021
[17] Bellut-Staeck, 2023; Bellut-Staeck, 2024; and see also **FIG 3**.

fibrosis[18]. Similar findings can be seen in the studies carried out by Liu Z et. al, 2012[19], Pei Z et. al., 2011[20] and Zhang MY et. al, 2016[21].

In addition, empiric data in experimental studies show clear indications that exposure to infrasound leads to an increase in Reactive Oxygen Species (*ROS*)[22].

Also, the study by Chaban et al., 2021[23] indicates positive evidence of direct cell effect caused by infrasound, while the study by Zhang H et. al., 2013[24] shows the effect of infrasound on the growth of colorectal carcinoma in mice.

A recent study shows alarming data on the negative effects of wind turbines (at a distance of at least 10 kilometres) on plant[25].

d) *Conclusion*

All organisms are equipped with mechano-sensors, in particular with PIEZO channels. For this reason, all organisms can be affected by infrasound with special properties. From bacteria to crabs, fish and birds, insects, whales, invertebrates, vertebrates and plants. Force transduction, also known as *mechanotransduction*, is an overarching ancient principle of *maintaining structure, function and communication* based on the current state of knowledge in PIEZO research[26]. This means that the increasing use of infrasound emitters with specific characteristics such as those used in IWT impulses in particular poses a threat to biodiversity as a whole. At low frequencies, a reassessment and re-evaluation of their effects on humans, animals and plants is urgently needed to avert

[18] Louisinha A, Oliveira RMJ, Borrecho G, Brito J, Oliveira P, Oliveira da Carvalho A, et al. *Infrasound induces coronary perivascular fibrosis in rats*. Cardiovascular Pathology. 2018;37: 39-44. Available: https://doi.org/10.1016/j.carpath.2018.10.004 [**Louisinha et. al., 2018**].

[19] Liu Z, Gong L, Li X, et al. *Infrasound increases intracellular calcium concentration and induces apoptosis in hippocampi of adult rats*. Molecular Medicine Reports. 2012;5: 73-77. Available: https://doi.org/10.3892/mmr.2011.597 [**Liu et. Al, 2012**].

[20] Pei Z, Chen BY, Tie R, et al. Infrasound exposure induces apoptosis of rat cardiac myocytes by regulating the expression of apoptosis-related proteins. Cardiovascular Toxicology. 2011;11: 341-3 Available: https://doi.org/10.1007/s12012-011-9126-y [**Pei et. al., 2011**].

[21] Zhang MY, Chen C, Xie XJ, et al. *Damage to Hippocampus of rats after being exposed to infrasound*. Biomedical and Environmental Sciences. 2016;29: 435-442 [**Zhang et. al., 2016**].

[22] Zhou X, Yang Q, Song F, et al. *Tetrahydroxystilbene glucoside ameliorates infrasound-induced central nervous system (CNS) injury by improving antioxidant and anti-inflammatory capacity*. Oxidative Medicine and Cellular Longevity. 2020; Article ID: 6576718; and Botts et. al., 2021.

[23] Chaban R, Ghazy A, Georgiadem E, Stumpf N, Vahl CF. *Negative effect of high-level infrasound on human myocardial contractility*: In vitro Controlled Experiment. Noise Health. 2021;23: 57-66 [**Chaban et. al., 2021**].

[24] Zhang H, Qi P, Si SY, Ma WM. *Effect of infrasound on the growth of colorectal carcinoma in mouse*. Chinese Journal of Cancer Prevention and Treatment. 2013; 20:1145-1149 [**Zhang et. al., 2013**]

[25] Li Gao, Qingyang Wu, Jixiang Qiu, Yingdan Mei, Yiran Yao, Lina Meng and Pengfei Liu. *The impact of wind energy on plant biomass production in China*. Scientific Reports | (2023) 13:22366 | https://doi.org/10.1038/s41598-023-49650-9. [**Li Gao et. al., 2023**.]

[26] Xiang-Zhi Fang, Ting Zhou1, Ji-Qian Xu, Ya-Xin Wang, Miao-Miao Sun, Ya-Jun He, Shang-Wen Pan, Wei Xiong, Zhe-Kang Peng, Xue-Hui Gao and You Shang1. *Structure, kinetic properties and biological function of mechanosensitive Piezo channels*. Fang et al. Cell Biosci (2021) 11:13 https://doi.org/10.1186/s13578-020-00522-z. [**Fang et. al., 2021**].

damage. Appropriate precautions must be taken until all scientific questions have been definitively answered.

with

Part 2: Review of the *Wind Turbine Noise and Health Study: Summary of Results* prepared by Health Canada

In this section, I provide my opinion on the *Wind Turbine Noise (WTN) and Health Study: Summary of Results* prepared by Health Canada (the "Study").

a) *Mixing of the audible noise components, measured in dBA (A-weighted dB) with the inaudible low-frequency components emitted by wind turbines*

Firstly, I note that the Study findings was based on an *epidemiological study,* which was subsequently published in 2016[27]. Michaud et. al., 2016 reveals the procedure that was utilized for the collection of data that was later statistically analysed. The data collected includes, *inter alia*, self-reported complaints of the residents and further raw data on which the statistical evaluations were then based on. Based on the state of knowledge at the time of the Study, the interviewers' questions were particularly aimed at the *audibility* of the wind turbines in order to be able to draw conclusions about the level of annoyance as well as health complaints and illnesses regarding the infrasound emissions.

Here is the quote from the original text of the above study on point C *Data collection*:
"2. Long-term high annoyance:

To evaluate the prevalence of annoyance, participants, were initially asked to spontaneously identify sources of noise, they hear originating from outdoors while they are either inside or outside their home. The interviewer grouped the responses as road traffic, aircraft, railway/trains, wind turbine, and "other." Follow-up questions were designed to confirm the initial response where the participant may not have spontaneously identified wind turbines, rail, road and aircraft as one of the audible sources. For each audible noise source participants were asked to respond to the following question from ISO/TS (2003a): "Thinking about the last year or so, when you are at home, how much does noise from [SOURCE] bother, disturb or annoy you?" Response categories included the following: "not at all," "slightly," "moderately," "very," or "extremely." Participants who reported they did not hear a particular source of noise, were classified into a "do not hear" group and retained in analysis (to ensure that the correct sample size was accounted for in the modeling). The analysis of annoyance was performed after collapsing the response categories into two groups (i.e., "highly annoyed" and "not highly annoyed"). As per ISO/TS (2003a), participants reporting to be either "very" or "extremely" annoyed were treated as "highly annoyed" in the analysis. The "not highly annoyed" group was composed of participants from the remaining response categories in addition to those who did not hear wind turbines. Similarly, an analysis of the percentage highly subjectively sleeps disturbed, highly noise sensitive, and highly concerned about physical safety from having wind turbines in the area was carried out applying the same classification approach used for annoyance."

The nature of the questions asked by the interviewers automatically led to a mixing of the audible noise components, measured in dBA (A-weighted dB) with the inaudible low-frequency components emitted by wind turbines with the audible portions of the sound

[27] Michaud DS, Feder K, Stephen E., Voicescu SA, Marro L, Than J, Guay M, et al. *Exposure to wind turbine noise: Perceptual responses and reported health effects*. Article *in* The Journal of the Acoustical Society of America · March 2016. DOI: 10.1121/1.4942391 [**Michaud et. al., 2016**].

emissions from IWTs. The respondents were naturally unable to perceive the infrasound components acoustically. This means that the suitability of the survey to answer the actual question is not given.

b) *General Limitations of the Study*

The Study's objectives, as described in the *Research Objectives and Methodology* section of the Study were as follows:

- *"Investigate the prevalence of health effects or health indicators among a sample of Canadians exposed to WTN using both self-reported and objectively measured health outcomes;*
- *Apply statistical modeling in order to derive exposure response relationships between WTN levels and self-reported and objectively measured health outcomes; and*
- *Investigate the contribution of LFN and infrasound from wind turbines as a potential contributing factor towards adverse community reaction*."

However, the *Preliminary Research Findings* presented in the Study are limited by key limitations that were acknowledged in the Study as follows:

- *"Results may not be generalized to areas beyond the sample as the wind turbine locations in this study were not randomly selected from all possible sites operating in Canada;*
- *results do not permit any conclusions about causality; and,*
- *results should be considered in the context of all published peer-reviewed literature on the subject."*

As illustrated, the current peer-reviewed literature *shows a clear relationship between infrasound and impacts on humans, animals and plants*.

c) *Comments on the Study Population and Participation*

In the Study, it was stated that: "*All potential homes within approximately 600 m of a wind turbine were selected, as well as a random selection of homes between 600 m and 10 km. From these, one person between the ages of 18 and 79 years from each household was randomly selected to participate."*

Based on the choice of participants, many residents from the group between 600 metres and 10 kilometres were excluded by this selection in a possibly more highly populated area. Also, only adults were included in the Study. This also limits the Study's findings.

d) *Comments on the* Self-Reported Questionnaire Results

In the Self Reported Questionnaire Results section of the Study, it was stated that:

"*The following were not found to be associated with WTN exposure:*

- *self-reported sleep (e.g., general disturbance, use of sleep medication, diagnosed sleep disorders);*
- *self-reported illnesses (e.g., dizziness, tinnitus, prevalence of frequent migraines and headaches) and chronic health conditions (e.g., heart disease, high blood pressure and diabetes); and*
- *self-reported perceived stress and quality of life."*

"While some individuals reported some of the health conditions above, the prevalence was not found to change in relation to WTN levels."

Based on my review of the paper published in 2016 following the Study[28], the survey asked whether the participants could *hear* the wind turbines and distinguish them from road noise and/or aircraft noise.

As explained above, low frequencies below 20 hertz (this is precisely their characteristic) are not audible with the ears; nevertheless, they are a physical force that are dissipated. Individual differences may exist, and some people can perceive sounds down to about 16 hertz. This means that the question itself does not allow any assignment to sources of infrasound and lead to a mixing of audible sources, either the audible noises of the WTN, street noise and/ or aircraft noise. Using these raw data as a starting point for assessing annoyance and adverse health effects of infrasound inevitably leads to false results even with the data entered.

e) <u>*Comments on the Study design*</u>

In the paper published in 2016[29], the following statement was provided in connection with the Study design:

1) *"The target population consisted of adults, aged 18 to 79 years, living in communities within approximately 10 km of a wind turbine in southwestern Ontario (ON) and Prince Edward Island (PEI*)."

2) *"The ON and PEI sampling areas included 315 and 84 wind turbines, respectively. Wind turbine electrical power output ranged between 660 kW to 3MW (average 2.060.4 MW). All turbines were modern design with 3 pitch-controlled rotor blades (80m diameter) upwind of the tower, and predominantly 80m hub heights."*

In 2012, the rotors of wind turbine blades were significantly smaller depending on the overall size of the wind turbines. This is crucial for the depth of the frequency in hertz. This results in a significant decrease in the infrasound frequencies emitted and the range, which in turn plays a significant role in the impact on the health of local residents.

In relation to the proposed Oyen wind power project, the rotor length is 85 metres, giving a rotor diameter of about 170 metres. The rotors for the proposed Oyen wind turbines are

[28] Michaud et. al., 2016.
[29] Michaud et. al., 2016.

approximately *double the length* of the wind turbine rotors in the two Canadian provinces of Ontario (ON) and Prince Edward Island (PEI).

Also, the planned 5.5/5,6 MW Oyen wind turbines are not at all comparable with the 2012 wind turbines in terms of their rated power and emissions such as infrasound. The increase in both nominal power and emissions (heat, audible sound and infrasound) is not linear in relation to the rotor blade length and the area swept, but to the *third power*. With increasing wind, the effect is intensified. This means *a disproportionate increase not only the output, but also* the harmful emissions. The increasing size of wind turbines also leads to a greater range.

As already noted above, the choice of participants between the ages of 18 and 79 for the Study is quite limited. The Study excluded the more sensitive group of children, adolescents and unborn children. Meanwhile, there are data on the influence of infrasound emitted by wind turbines, which indicates mutagenic effects and negative effects on fertility. Data on this can be found in the Dumbrille et. al., 2021 study as well as in a study from Portugal on mutagenic effects in foals[30]. Many observations, particularly of farm animals, were not recorded in a Study.

According to the current state of knowledge, the importance of external forces such as repeated exposure to low frequencies and vibration during the pregnancy stage must be classified as significantly greater than previously assumed. The sensitivity is related to various stages particularly of embryonic development, which are physiologically based on an undisturbed flow. Deeper insights are provided in the research carried out by Hahn and Schwartz[31] and Fang et al[32].

f) *Measurement Limitations*

In the 2016 paper[33], it was stated that:

> *"Low frequency noise was estimated**,** in the CNHS by calculating outdoor C-weighted sound pressure levels at all dwellings. There was no additional gain by analysing the data using C-weighted levels because the statistical correlation between C-weighted and A-weighted levels was very high (i.e., r ¼ 0.81–0.97) (Keith et al., 2016a)*

This presents limitations to the Study. First, estimates instead of real measurements were made. In addition, it remains unclear as to the depth the frequency in 2012 was even

[30] Costa Pereira e Curto T, *Acquired flexural deformation of the distal interphalangeal joint in foals*. Dissertation Faculty of Veterinary Medicine. 2012 Lisboa [**Costa, 2012**].

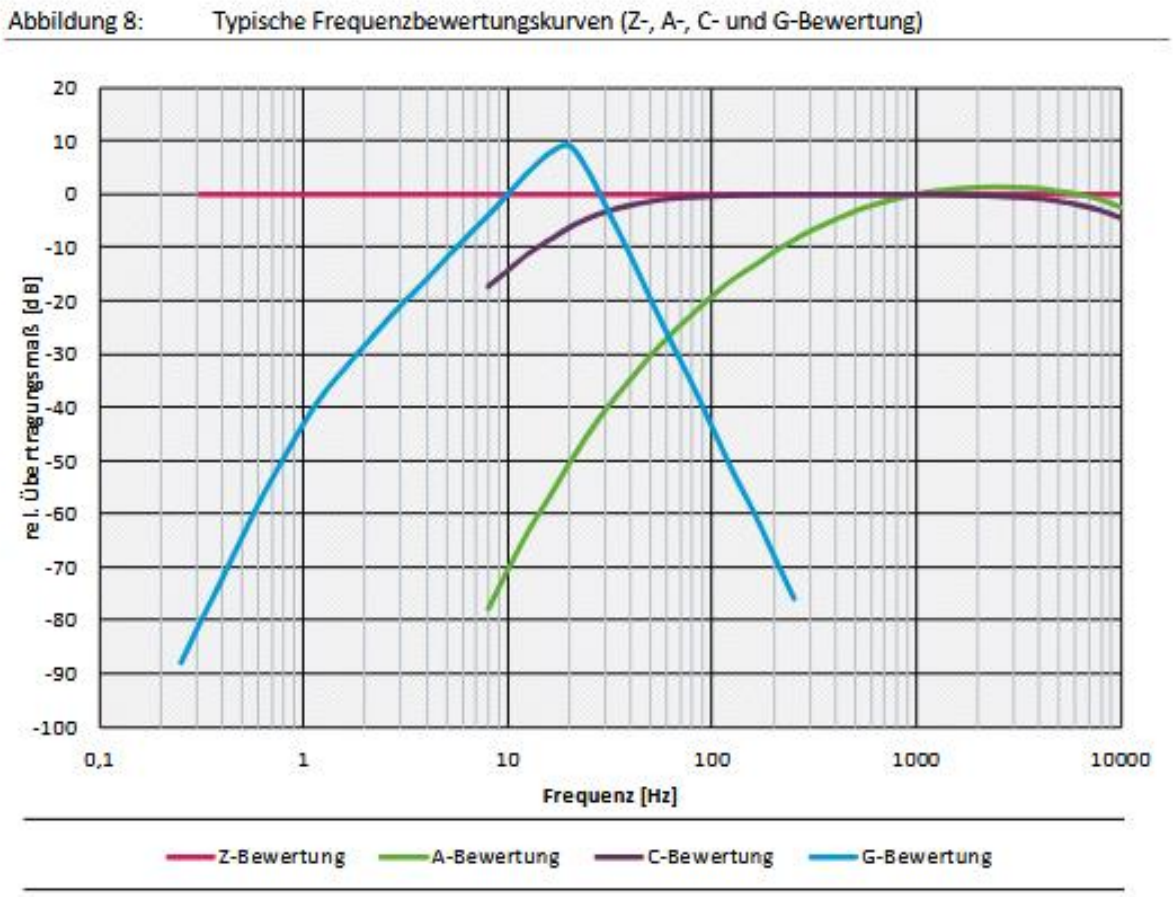
[31] Hahn C, Schwartz MA. Mechanotransduction in vascular physiology and atherogenesis. Nature Reviews Molecular Cell Biology. 2009; 10: 53-62. Available: https://doi.org/10.1038/nrm2596

[32] Xiang-Zhi Fang, Ting Zhou1, Ji-Qian Xu, Ya-Xin Wang, Miao-Miao Sun, Ya-Jun He, Shang-Wen Pan, Wei Xiong, Zhe-Kang Peng, Xue-Hui Gao and You Shang1. Structure, kinetic properties and biological function of mechanosensitive Piezo channels. Fang et al. Cell Biosci (2021) 11:13 https://doi.org/10.1186/s13578-020-00522-z.

[33] Michaud et. al, 2016.

possible for meteorological reasons. The following **FIG. 4** shows the problem of A- and C, G- weighted measurements for infrasound.

FIG. 4



Typical frequency weighting curves for Z-, A-, C- and G-weighting in original source[34].

The following can be, inter alia, derived from the graph:

The A- (A for acoustic) and C-rating can only measure the range *only* down to 8 Hz frequencies, which can be demonstrated that the A-rating for example for 10 Hz in the low-frequency range reduces the correct rating by 70 dB. The difference between an A-rating and a C- rating can indicate the presence of infrasound (cave: only up to 8 Hz, not below), but cannot measure it quantitatively.

The G-rating covers a lower frequency range, but with significant reductions in realistic sound pressures. It has been shown that the main sources of low-frequency emissions

[34] TEXTE 134/2020 Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit. Forschungskennzahl 3713 53 100 FB000232. Ermittlung und Bewertung tieffrequenter Geräusche in der Umgebung von Wohnbebauung. Abschlussbericht.

from WTN are in a range between 0.2 and 8 Hz. Only a Z-rating (unheightened) can reproduce infrasound down to very low levels on general acoustical opinion today.

g) *Comments* on Sleep *Quality*

In the Study section dealing with the *Objectively Measured Results,* it was stated that there was no association found between sleep quality and WTN.

However, sleep disorders are one of the main problems of residents living near wind farms. In this context, I refer to the study by Alun Evans, 2017[35], as well as to the study by Weichenberger et. al., 2017[36], in which an activation of various brain centres, including those for fear and flight and emotion was demonstrated by *fMRI*. The subjects perceived the effect of infrasound *without any auditory perception*.

h) *Comments on Perception of Community Noise and Related Variables as a function of WTN Level*

In the 2016 publication[37], various functional disorders such as tinnitus, migraine, dizziness, manifest illnesses and quality of life were queried and again related to different dBA exposure values. This in turn fails again to meet the requirement to establish a link between infrasound and functional complaints and/or manifest illnesses.

The data collected in this way cannot be linked to the exposure to infrasound, but obviously were included as raw data in the statistical analyses, which cannot lead to an accurate representation of the relationship between exposure to infrasound and health complaints and manifest illnesses. The only objective criterion found to be statistically relevant was the consumption of sleeping pills.

i) *Comments on the Concluding Remarks*

In the 2016 publication[38], the authors made the following concluding remarks:

"Study findings indicate that annoyance toward all features related to wind turbines, including noise, vibrations, shadow flicker, aircraft warning lights and the visual impact, increased as WTN levels increased. The observed increase in annoyance tended to occur when WTN levels exceeded 35 dB and were undiminished between 40 and 46 dB. Beyond annoyance, the current study does not support an association between exposures to WTN up to 46 dB and the evaluated health-related endpoints."

[35] Evans A. *Environmental noise pollution: Has public health become too utilitarian*? Open Journal of Social Sciences. 2017;5: 80-107. Available: https: //doi.org/10.4236/jss.2017.55007
[36] Weichenberger et. al., 2017.
[37] Michaud et. al., 2016.
[38] Michaud et. al., 2016.

The first statement in the concluding remarks is based on obvious reasons. Of course, all the conditions associated with a wind turbine facility cumulatively led to impairments and a significant reduction in the quality of life.

However, the actual question of the impacts of infrasound was not answered. This question could not be answered by the Study because as explained in my comments above, A weighted WTN levels can only be used as a measurement standard for the acoustic range, and thus not for the assessment of the infrasound range.

I will come back to the limitations noted in the *Preliminary Research Findings* section of the Study as follows:

- *"results may not be generalized to areas beyond the sample as the wind turbine locations in this study were not randomly selected from all possible sites operating in Canada;*
- *results do not permit any conclusions about causality; and,*
- *results should be considered in the context of all published peer-reviewed literature on the subject."*

Based on the state of knowledge in 2012, which took the auditory impression as the main criterion for an effect, the associated faulty raw data, and the other weaknesses of the study design mentioned above, the second limitation statement as noted in the *Preliminary Section Findings* must be confirmed.

j) *My Conclusion on the Study*

From my assessment of the Study and the subsequent paper published in 2016, my position is that the Study does not provide an up-to-date analysis of the relationship between deep frequencies and serious health effects.

As the Study and the publication are based on a timeframe between 2012 and 2016, the Study does not consider findings from international studies on the subject from 2017 onwards. Clearly, the Study does not reflect the current state of knowledge on the subject. The current scientific progress on the subject is not taken into account. The Study principally refers to the sound pressure level (SPL) in dBA. dBA is an assessment criterion that can be used for the audible (i.e., non-infrasonic range) and not for the inaudible range.

Statement regarding comments made by Dr C. Ollson

Regarding my CV, scientific status and previous scientific work, which, with the exception of one publication, could be found in the appendix of the paper below:
Chronic Infrasound Impact is Suspected of Causing Irregular Information via Endothelial Mechano-transduction and Farreaching Disturbance of Vascular Regulation in All Organisms. Medical Research and Its
Applications Vol. 8 (2024) (Exhibit 29226-X0140, pg. 108-140. 2)

Biography of author(s)

Ursula Maria Bellut-Staeck (MD)
Independent Scientist, Berlin, Germany.

Research and Academic Experience: She studied human medicine at the Westfälische Wilhelms-Universität Münster and Eberhard Karls Universität Tübingen, Germany. She completed her Doctor of Medicine on October 1, 1984; her study was on "Preservative perfusion of isolated dog kidneys with oxygen-transporting FluosolR -43 with particular consideration of vitality criteria". She is a specialist in general medicine, a specialist in emergency medicine, and has an additional qualification in radiation protection.

Research Specialization: Her areas of research mainly include microcirculation, intensive care medicine, cardiovascular physiology and pathophysiology, and vascular biology.

Number of Published papers: She has 2 scientific publications, which are as follows:

1. Bellut-Staeck UM. Microcirculation and its importance for all life. Subtitle: Current findings on the vital functions of endothelial cells. In Series Titles: Essentials. Publisher Springer Berlin, Heidelberg; 2022.
2. Bellut-Staeck UM. Impairment of the endothelium and disorder of microcirculation in humans and animals exposed to infrasound due to irregular mechano-transduction: Journal of Biosciences and Medicine. 2023; 11(6). DOI: 10.4236/jbm.2023.116003

Any other remarkable point(s): She is a Conservationist.

DISCLAIMER
This chapter is an extended version of the article published by the same author(s) in the following journal.
Journal of Biosciences and Medicines, 11: 30-56, 2023. Available:https://doi.org/10.4236/jbm.2023.116003

Peer-Review History:
This chapter was reviewed by following the Advanced Open Peer Review policy. This chapter was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/727

The scientific paper not listed appeared in the German medical weekly DMW (Thieme Verlag 2022).

*Dtsch Med Wochenschrift 2022; Windenergieturbinen und Schallbelastungen im hörbaren und IFLN-Bereich: Hohe Evidenz für schwere Gesundheitsstörungen nach aktueller Studienlag**e;***
Wind energy turbines and sound exposure in the audible and IFLN range: high evidence for severe health disturbances according to current studies. 147(18): 1222-1223
DOI: 10.1055/a-1813-8373

The scientific presentation of the current state of knowledge on microcirculation and endothelial functions for Springer Nature

Bellut-Staeck UM. (2022) Die Mikrozirkulation und Ihre Bedeutung für alles Leben. Neue Erkenntnisse zu wesentlichen Funktionen von Endothelzellen. In Series Titles: Essentials. Publisher Springer Berlin, Heidelberg; Book 2022, (eBook) DOI: https://link.springer.com/book/10.1007/978-3-662-66516-9

The scientific work on the current state of knowledge regarding microcirculation and endothelial functions was published in the Springer Nature Essentials 2022 series. The two peer-reviewed papers are also based on this current state of knowledge, as can be seen from the quality and timeliness of the scientific sources.

The difference between the two peer-reviewed papers can be seen from the following comment from me.
The first publication presented the possible consequences of the conflict for the first time in (1) 6/23.
The second publication (2) 06/24 on the topic is essentially based on the first (1) and specifically expands on important aspects of the topic, e.g.:
1) the possible effects on the N0 metabolism [19,20,22] with a strong increase in oxidative and oscillatory stress
2) the role of the endothelium as a central organ for inflammatory development as the basis e.g., of arteriosclerosis [2,22] or blood pressure disease
3) the outstanding importance of PIEZO channels [49] for numerous functions of organ organisms
4) the associated risk to all living organisms in terms of a threat to biodiversity on land and in water

As you can see in the corresponding chapter 5 of the book (2), an open review policy was implemented by several publicly appointed high-ranking scientists. The reviews to be read attest to the scientific rigour, the broad relevance to the scientific community and the quality of the sources used.

Extract:

Peer-Review History

This chapter was reviewed by following the *Advanced Open Peer Review policy*. This chapter was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/727

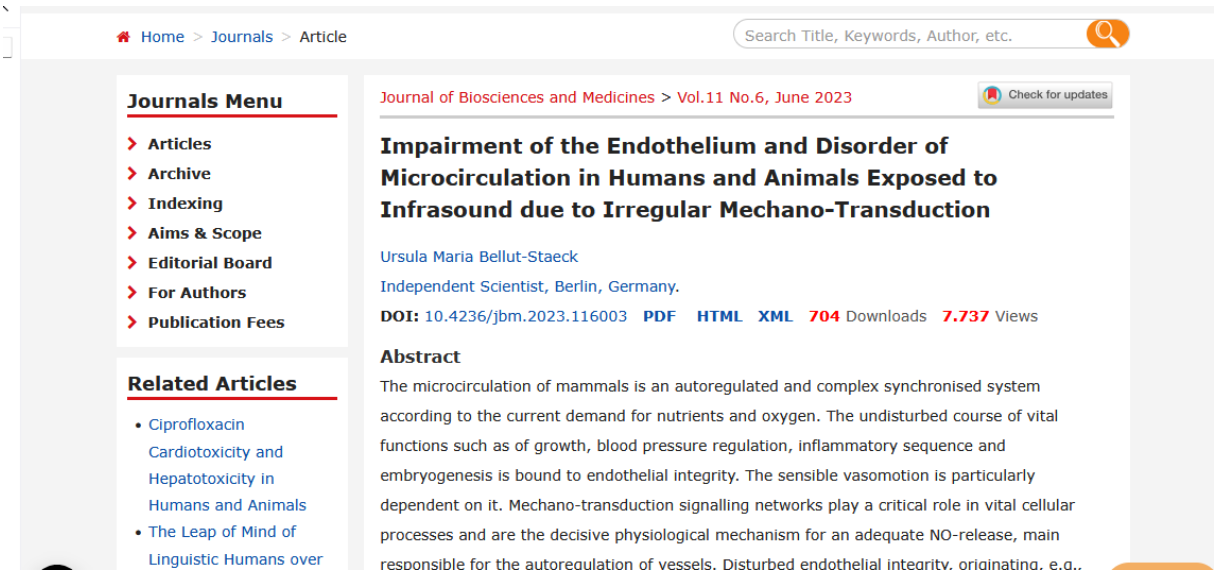
1) Bellut-Staeck UM. (2023) *Impairment of the endothelium and disorder of microcirculation in humans and animals exposed to infrasound due to irregular mechano-transduction*: Journal of Biosciences and Medicine. 2023; 11(6). DOI: 10.4236/jbm.2023.116003 Link: https://www.scirp.org/journal/paperinformation?paperid=125553

2) Bellut-Staeck UM. (2024) *Medical Research and Its Applications Vol. 8, Chap. 5 Chronic Infrasound Impact is Suspected of Causing Irregular Information via Endothelial Mechanotransduction and Far-reaching Disturbance of Vascular Regulation in All Organisms*. FIRST EDITION 2024 ISBN 978-81-975566-2-3 (Print), ISBN 978-81-975566-5-4 (eBook) DOI: https://doi.org/10.9734/bpi/mria/v8

I have been working in the specialised field of microcirculation, physiology and pathophysiology of vascular regulation since 2004 and, with increasing scientific knowledge since 2000, with vital endothelial functions. In addition to my scientific work, I continue to work as a doctor specialising in general medicine and emergency medicine.

The important question that arises is whether a scientist in the field of sociology is able to assess and provide a qualified evaluation of complex medical facts that are based on the very latest international knowledge and required a two-year literature search, as well as being reviewed about 10 times. To Dr Ohlson's credit, the public could have become aware of the need for a reassessment of infrasound at the latest after the 2021 Nobel Prize in Medicine was awarded, but even the medical community probably needs more time to process this knowledge. However, a further failure to take into account the knowledge that already exists regarding the absorption of force and sound at the organ level is associated with potentially serious consequences for the environment. For this reason, the state of knowledge must be taken into account and the hypothesis must be verified or falsified. The two scientific papers stand up to any professional review in the fields of medicine, vascular physiology and microcirculation.

Current status of views and downloads of the paper 1) as of today, 13/04/25:



Part 3 – Review of Expert Opinion from Christopher A. Ollson, Ph.D.

In this section, I provide comments on Appendix B *(Infrasound and Wind Turbine Projects*) and Appendix C (*Literature Review on Potential Effects on Livestock and Mammalian Wildlife*) of the Expert Report of Christopher A. Ollson, Ph.D. (the "Ollson Report"). In doing this, I refer to specific sections of the Ollson Report and provide my comments on the same.

Review of Appendix B *(Infrasound and Wind Turbine Projects*)

a) Comment on Sound Frequency

At PDF page 48 of Appendix B of the Ollson Report, it was stated that:

> *"Some sounds have higher SPL [sound pressure levels] in the lower frequencies (for example sound from a bass speaker typically ranges between 60 – 250 Hz). In this case the C-weighted filter maybe a more appropriate scale (dBC) of how humans perceive its loudness, as it includes a greater contribution from the lower frequencies than the A-weighted filter." [...]*

I have already explained in detail the suitability of various weightings on the basis of the graphic **figure 4** in Part 2 of my report. As noted above, low frequencies can only be measured and categorised using an unweighted, i.e., Z- weighting.

Although I am not an expert in acoustics by profession, but through the scientific study of low frequencies and working with acousticians and physicists for over 8 years, I have experience relating to sound weightings and their usefulness. In the case of infrasound, we have to consider not only the recording through the ear, but also the scientifically appropriate recording of low frequencies at the mechano-sensor level.

Further, at PDF page 48 of Appendix B of the Ollson Report, it was stated that:

> *"Infrasound is a term used to describe sounds that are produced at frequencies (0 to 20 Hz) too low to be heard by the human ear, at common everyday levels. It is typically reported unweighted or on the G-weighted scale (dBG), which was specifically designed for the assessment of infrasound where each frequency is weighted in accordance to its relative contribution to perception. It is a common misunderstanding that infrasound is inaudible. Although this is true for typical environmental infrasound levels, the audibility threshold on the dBG scale is between 85 to 95 dBG. To reach these levels one must usually be in an occupational or laboratory setting."*

I am aware of the considerations of infrasound at very high decibel levels. For example, the infrasound frequency of 1 Hz has been assigned a sound intensity of about 120 dB so that a test subject "could hear" it[39]. (Umweltbundesamt UBA Germany). This was referred

[39] Krahé D, Schreckenberg D, Ebner F, Eulitz C, Möhler U. Machbarkeitsstudie zu Wirkungen von Infraschall. Entwicklung von Untersuchungsdesigns für die Ermittlung der Auswirkungen von Infraschall auf den

to as the so-called acoustic perception threshold and equated with the infrasound effects. According to the current state of science, *this is no longer valid*.

b) Comments on Permissible Sound Levels

At PDF page 49 of Appendix B of the Ollson Report, it was stated that:

> "[...] *These sound standards are on the A-weighted scale, which is common around the world for setting standards related to environmental noise, such as that from wind turbines. [...]* ***The result is that AUC Rule 012 is one of the most conservative wind turbine sound standards published by any regulatory authority around the world governing wind turbine sound.*** *"*

Previously valid standards for measuring infrasound must be adapted to the current *state of science*. The validity of the *A-weighted scale* only exists for the acoustically audible portion of wind turbine emissions, but not for frequencies under 20 Hertz. See please Part 1 of my report in this regard.

c) Comments on Infrasound and Low Frequency Noise from Wind Turbines and Potential Health Impacts

At PDF page 49 of Appendix B of the Ollson Report, it was stated that:

> *"Universally wind turbine sound standards are set using audible dBA levels, as they are in Alberta, and approved based on modeling. Over the past couple of years there have been a limited number of researchers that have speculated that wind turbine infrasound and LFN could be the potential cause of potential health impacts or sleep disturbance. The mere presence of measured LFN and infrasound does not indicate a potential threat to health or an inability for people to sleep."*

In Parts 1 and 2 of my report, I provided information on the state of scientific knowledge, including studies on infrasound. In particular, my paper on chronic infrasound impact[40] was reviewed by renowned scientists as part of an open-review process and has been confirmed in its stringency, consistency and evidence. The state of scientific knowledge, my peer-reviewed papers[41] and the studies by other researchers are not *speculative*. They show a causative link between infrasound and health impacts and sleep disturbance. In this context, I have cited all the sources that I have mentioned, in particular also the study by Dumbrille et al., 2021.

At PDF page 50 of Appendix B of the Ollson Report, it was stated that:

> *"Although wind turbines are a source of LFN and infrasound during operation, these sound pressure levels are not unique to wind turbines. Common natural*

Menschen durch unterschiedliche Quellen. Verlag Umweltbundesamt; 2014 Available: https://www.umweltbundesamt.de/publikationen/machbarkeitsstudie-zu-wirkungenvon-infraschall

[40] Bellut-Staeck, 2024.

[41] Bellut-Staeck, 2023; and Bellut-Staeck, 2024.

sources of LFN and infrasound include ocean waves, thunder, and even the wind itself. Other human sources include road traffic, refrigerators, air conditioners, oil pump jacks, farm machinery, and airplanes."

The main difference between low-frequency emissions from technical wind turbines and others lies in the following factors:

- the periodicity, a chronically timed event, possibly 12/24;
- the depth of the frequencies up to 0.25 Hz with possible resonance effects[42];
- the impulsivity, rapidly accelerating pressure at the beginning of the time/effect profile[43].

Further, sounds from the natural environment are limited such as a thunderstorm or an earthquake. There is an immediate recovery possibility of the microcirculation. With respect to longer flights or car journeys (which happen contrary to natural phenomena voluntarily or are already subject to restrictions due to vibration and infrasound, a typical example being stewardesses), such occurrences have precautionary measures placed on them (e.g. labour law) to reduce the exposure to constant infrasound and vibrations. As such, sensitive groups are already protected, which is not the case in the residential environment where residents have no choice but to live within the proximity of the wind turbines.

Also, engines (e.g., oil pump jacks, farm machineries, *etc*.) can certainly be sources of infrasound, and possible protective measures should be considered and taken against those engines. However, none of these sources is comparable in terms of all qualities to emissions from wind turbines, particularly the fact that the infrasound from wind turbines is continuous and thus leads to a longer-term exposure. It must be recognized that every organism will become exhausted when subjected to a chronic stressor; the resilience varies from individual to individual.

As for the wind itself, I have to say that it is a background noise in contrast to the periodically emitted impulses of a wind turbine.

d) Comment on the conclusion from Berger et al., 2015 Health-based Audible Noise Guidelines Account for Infrasound and Low Frequency Noise Produced by Wind Turbines" in the journal Frontiers in Public Health Vol 3, Art. 31.

At PDF page 50 of Appendix B of the Ollson Report, it was stated that:

*"The analysis showed that indoor infrasound levels were below auditory threshold levels while LFN levels at generally accepted setback distances were similar to background LFN levels." [...] "**These guidelines for infrasound will not be reached in homes situated near wind turbine projects.** Quite simply, **the homes will be located too far back from the turbines based on audible sound criteria to have the accompanying infrasound levels exceed these guidelines.** In fact, these*

[42] Persinger, 2014.
[43] Persinger, 2014; and Vanderkooy et. al., 2014.

levels of infrasound are not reached even near the base of the wind turbines themselves."

As already mentioned, the auditory perception threshold cannot provide any information on the effect of infrasound and does not offer any certainty.

e) *Comments on Turnbull C, Turner J, Walsh D. 2012. Measurement and level of infrasound from wind farms and other sources. Acoust Aust **40**:45-50.*

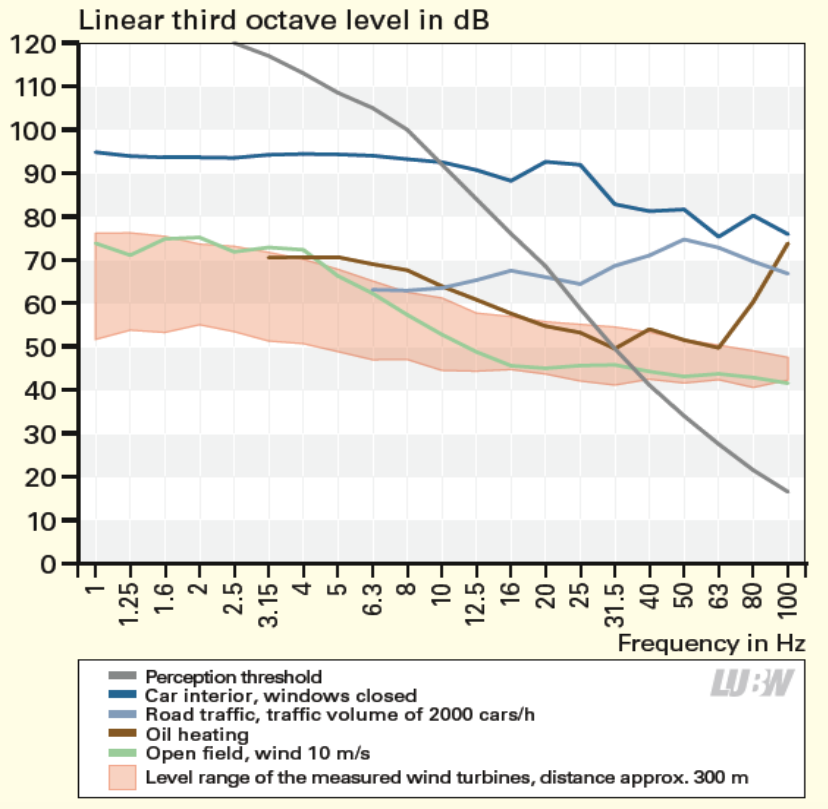
The study is from 2012 and the study used the acoustic perception threshold as a measure of the effect of infrasound. The use of acoustic perception for infrasound is limiting and does not provide accurate findings.

f) *Comments on studies by Keith et. al., 2016 and Michaud et. al., 2016*

See part 2 of my report on this.

g) *Comments on Ministry for the Environment, Climate and Energy of the Federal State of Bade Wuerttemberg Germany. (MECE) 2016. Low-frequency noise including infrasound from wind turbines and other sources.*

I note the Figure 2 at PDF page 53 of the Ollson Report, reproduced below:



This assessment from 2016 is based on outdated knowledge. The graph shows the increasing range of infrasound and the acoustic perception threshold, which *cannot* be assessed as the effective threshold for infrasound.

h) Comments on Van Kamp, I & van den Berg, F. 2018. Health Effects Related to Wind Turbine Sound, Including Low-Frequency Sound and Infrasound Acoust Aust (2018) 46:31–57

The authors concluded that:

> *"Vibroacoustic disease and the wind turbine syndrome are controversial and scientifically not supported. At the present levels of wind turbine sound, the alleged occurrence of vibroacoustic disease (VAD) or the disease (VVVD) causing the wind turbine syndrome (WTS) is unproven and unlikely."*

However, the new state of knowledge now allows the symptoms of vibroacoustic syndrome to be categorized, and a causal relationship established. For this, compare the re-evaluation of histopathological images for the vibroacoustic syndrome in my recent paper.[44]

i) Comments on Van Kamp*, I & van den Berg, F. 2021. Health Effects Related to Wind Turbine Sound: An Update. Int. J. Environ. Res. Public Health 2021, 18, 9133*

The authors stated that*:*

> *"There is no indication that the low-frequency component has other effects on residents other than normal sound nor that infrasound well below the hearing threshold can have any effect"*.

The current state of scientific knowledge regarding the absorption of sound outside the ear was not taken into account here, particularly the 2021 study on PIEZO-channels as noted above. This limits the validity of the findings.

j) Comments on Marshall et al. 2023. The Health Effects of 72 Hours of Simulated Wind Turbine Infrasound: A Double- Blind Randomized Crossover Study in Noise-Sensitive, Healthy Adults. Environmental Health Perspectives. 131(3) March 2023

The authors noted that:

> *"Our findings did not support the idea that infrasound cause WTS [Wind Turbine Syndrome]. High level, but inaudible, infrasound did not appear to perturb any physiological or psychological measure tested in these study participants"*.

In the study mentioned in part 2 of my report by Weichenberger et. al., 2017, an fMRI was carried out during the exposure to an acoustically inaudible infrasonic sound (double-blind). The examination was carried out at the same time. This showed relevant activations in specific brain areas that are responsible, among other things, for emotional control and fear centre. Another area was activated that is responsible for controlling blood pressure and pulse rate. The transfer of information via a force into information

[44]Bellut-Staeck, 2024.

(called biophysical way) takes place immediately, in milliseconds[45]. This means that a test result can only be obtained if infrasound and suitable examination methods are used at the same time.

k) Comments on Conclusion on Low Frequency Noise and Infrasound and the AUC Findings on Low Frequency Noise and Infrasound

At PDF page 55 of Appendix B of the Ollson Report, the following were stated:

> *"The hypothesis that low frequency noise or infrasound from wind turbines is a causative agent in health effects or sleep disturbance* ***is not supported by the scientific and medical literature****"*.
>
> *"[...]. The Commission finds the CCCOG [Concerned Cypress County Owners Group] has not provided technical or expert evidence showing that noise or shadow flicker may cause adverse health effects. "*

The current state of knowledge requires a *paradigm shift*. The work by Ardem Patapoutian (which led to the award of the Nobel Prize in Medicine in 2021), which classified PIEZO channels as currently the most important group of mechano-sensors and a crucially newly recognised level of perception of physical forces and sound in all living things must be incorporated into studies on infrasound and decisions regarding new wind farms in order to be able to recognise and avert harm to the population, animals and nature. Before large wind turbines can continue to be approved, there must be a reassessment of the impacts of low frequencies.

Although I have not focused on shadow flicker: shadow flicker is certainly an additional burden. It is important to note that the connection between chronic long-term stress and physical health is generally recognised. In addition, the change from light to shadow can trigger epilepsy and is dangerous for people who are sensitive to it.

Review of Appendix C (*Literature Review on Potential Effects on Livestock and Mammalian Wildlife*)

I agree with the position stated by Dr. C. Ollson that there are only very few peer-reviewed studies on the health effects of infrasound on animals. I also agree that the reindeer is a suitable test animal for the study.

However, the meta study by Dumbrille et al., 2021 documents mutagenic effects and reduced fertility. Also, the doctoral thesis by Costa, 2012 confirms mutagenic effects in foals.

As I noted in Part 2 of my report, embryonic processes are particularly dependent on an undisturbed laminar flow and must not be disturbed by external forces and sound effects or vibrations. This is also reflected in the special occupational health requirements at workplaces regarding the absence of low-frequency sound, pressure and vibration.

[45] Bellut-Staeck, 2024.

Further, the study by Li Gao et. al., 2023 on the effects of wind turbines show disturbing data on the significant decrease in biomass production in all variables. The investigations included over 2000 wind farms and over 100,000 wind turbines from 2000 to 2022.

Also, Stefan Garthe et. al., 2023[46] worked in their recent study on the decline in the population of loons in the North Sea. The study shows a significant decline in loons' population at comparable distances. In this study, the decline could be well documented, but this is very difficult or even impossible for other populations on or in or even under terrestrial areas to be similarly documented. One reason for this is that the permanent vibrations in the ground, caused by structure-borne sound, almost certainly leads to damage to the edaphic zone. If it is assumed that the decline in populations of loons in the North Sea as noted in the study by Stefan Garthe et. al., 2023 occurs in parallel with onshore wind turbines and therefore impacts the population of terrestrial animals including insects and bees, then this presents a clear danger to biodiversity.

Also relevant are the studies on reindeer in northern Sweden: Skarin et al., 2015; Skarin and Alam, 2016; and Skarin et al., 2018. The wind turbines caused females to move out of their usual calving rangeit leading to higher densities of reindeer in other parts of the herding. In Skarin et al., 2018: it was noted that: *"The continuous running of the wind turbines making a sound both day and night seemed to have disturbed the reindeer in our study area more than the sudden sounds and increased human activity during construction work, and as they had the possibility to move away from the WFs this caused significant changes in location of reindeer calving sites and habitat selection"*.

I note the statement of Dr. C. Ollson to the three long-term studies Skarin et al. as follows:

"*There are considerable regional differences and potentially numerous factors that led to inconsistent findings between these two research groups. It suggests is that although it is possible there could be some changes in reindeer habitat selection around wind projects, it is far from definitive and no population effects, regionally or locally, were reported by either group. I also note that caution should be used to avoid overinterpreting findings of these studies, either positive or negative, on populations of ungulates in southern Alberta*".

Notwithstanding the regional differences, the finding that the continuous running of the wind turbines making a sound both day and night seemed to have disturbed the reindeer in the study area cannot be ignored. As I explained above, every organism will become exhausted when subjected to a chronic stressor (in this case, the continuous running of the wind turbines).

I should also add that Norway's Supreme Court ruled in 2021 that the Storheia and Roan wind farms in Fosen in central Norway violated Sami rights under international

[46] Stefan Garthe, Henriette Schwemmer, Verena Peschko, Nele Markones, Sabine Müller, Philipp Schwemmer and Moritz Mercker. *Large-scale effects of offshore wind farms on seabirds of high conservation concern*. Scientific Reports (2023) 13:4779 | https://https://doi.org/10.1038/s41598-023-31601-z. [**Stefan et. al., 2023**]

conventions as the loss of winter pastures near Storheia and Roan will threaten reindeer husbandry's existence in Fosen[47].

[47] Lilja Mosesdottir, *Energy (in)justice in the green energy transition. The case of Fosen wind farms in Norway.* Technology in Society Volume 77, June 2024, 102563.

CONCLUSION

In conclusion, I would like to point out to the Commission that interventions in the natural environment and the surroundings of people and their assessment are, of course, always based on the state of science at that time. If our knowledge has changed, then it is imperative that this has be taken into account in the assessment of the impacts of infrasound. The consequences of this can often only be determined after years, as in the long-term study[48]. Our ability to constantly assess the situation must not be hampered by clinging to studies/facts that were previously valid. Findings by new studies must be considered.

Our responsibility for the health of humans, animals and nature now requires us to base our assessments, findings and decisions on a new foundation of knowledge. The new facts are abundantly clear, even if experimental proof is still needed to confirm the current state of scientific hypothesis. Notwithstanding the need for further experimental proof, preventive measures are urgently needed. Currently, there is clarity regarding the intake of sound outside the ear, the importance of maintaining endothelial integrity and the assessment of sound weighting. At stake is nothing less than a possible threat to the very basis of life at the microscopic level.

Ursula Bellut-Staeck, MD

[48] Li Gao et. al., 2023.

DISCLAIMER

For the author, there are no conflicts of interest.

The author would like to clarify that: Alternative forms of renewable energy such as industrial wind turbines are considered as valuable additions at *suitable locations*. The same is valid for biogas installations, heat pumps, and block-type thermal power stations. The data reported herein have been scrutinized under one, and only one agenda, that of pure scientific inquiry. There are no commercial, financial, or professional agreements or interests that contributed to, inspired or affected the outcome or the opinions expressed in this report. There are no competing interests affecting the author.

REFERENCES

1. Michaud DS, Feder K, Stephen E., Voicescu SA, Marro L, Than J, Guay M, et al. *Exposure to wind turbine noise: Perceptual responses and reported health effects*. Article *in* The Journal of the Acoustical Society of America · March 2016. DOI: 10.1121/1.4942391

2. Andolfo I, Alper SL, Iolascon A. Nobel prize in physiology or medicine 2021, receptors for temperature and touch: Implications for hematology. Commentary. 2021. DOI: 10.1002/ajh.26407

3. Fernandes CD, Araujo Thaıs S, Laurindo FRM, Tanaka LY. Cap. 7. Hemodynamic forces in the endothelium. mechanotransduction to implications on development of atherosclerosis. In: Da Luz PL, Libby P, Laurindo FRM, Chagas ACP, Eds., Endothelium and Cardiovascular Diseases. Vascular Biology and Clinical Syndromes, Mica Haley, Sao Paolo. 2018; 85-94

4. Bellut-Staeck UM. Die Mikrozirkulation und ihre Bedeutung für alles Leben. Untertitel: Aktuelle Erkenntnisse zu lebenswichtigen Funktionen von Endothelzellen. In Series Titels: Essentials. Publisher Springer Berlin, Heidelberg; 2022.
Available: https://doi.org/10.1007/978-3-662-66516-9.Softcover ISBN978-3-662-66515-2.

5. Bellut-Staeck UM. Impairment of the endothelium and disorder of microcirculation in humans and animals exposed to infrasound due to irregular mechano-transduction: Journal of Biosciences and Medicine. 2023; 11(6).
DOI: 10.4236/jbm.2023.116003

6. Botts SR, Fish JE and Howe KI. Dysfunctional Vascular Endothelium as a Driver of Atherosclerosis: Emerging Insights Into Pathogenesis and Treatment. frontiers in Pharmacology (2021) Doi: 10.3389/fphar.2021.787541

7. Pries AR. Coronary Microcirculatory Pathophysiology: Can we afford it to remain a black box? European Heart Journal. 2016; 38:478-488. Available: https://doi.org/10.1093/eurheartj/ehv760

8. Persinger A, Infrasound, human health, and adaptation: an integrative overview of recondite hazards in a complex environment. Nat Hazards (2014) 70:501–525 DOI 10.1007/s11069-013-0827-3

9. Weichenberger M, Bauer M, Kühler R, et al. Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold—evidence from fMRI. Plos One. 2017; 12: e0174420. Available: https://doi.org/10.1371/journal.pone.0174420

10. Vanderkooy J, Mann R. Measuring Wind Turbine Coherent Infrasound; Department of Computer Science 2 University of Waterloo, Waterloo, ON, Canada, N2L3G1 jv@uwaterloo.ca, mannr@uwaterloo.ca Date posted: 2 October, 2014

11. Mazzag, B. and Barakat, A.I. (2010) The Effect of Noisy Flow on Endothelial Cell Mechanotransduction: A Computational Study. *Annals of Biomedical Engineering*, **39**, 911-921. https://doi.org/10.1007/s10439-010-0181-5

12. Mazzag, B., Gouget, C., Hwang, Y. and Barakat, A.I. (2014) Cap. 5. Mechanical Force Transmission via the Cytoskeleton in Vascular Endothelial Cells. In: Rosado, J.A. and Redondo, P.C., Eds., *Endothelial Cytoskeleton*, CRC Press, Boca Raton, 91-115

13. Dumbrille A, McMurtry RY, Krogh Marie C. Wind turbines and adverse health effects: Applying Bradford Hill's criteria for causation. Environmental Disease. 2021; 6: 65-87 DOI:10.4103/ed.ed_24_21.

14. Costa Pereira e Curto T, Acquired flexural deformation of the distal interphalangeal joint in foals. Dissertation Faculty of Veterinary Medicine. 2012 Lisboa

15. Hahn C, Schwartz MA. Mechanotransduction in vascular physiology and atherogenesis. Nature Reviews Molecular Cell Biology. 2009; 10: 53-62. Available: https://doi.org/10.1038/nrm2596

16. Xiang-Zhi Fang, Ting Zhou, Ji-Qian Xu, Ya-Xin Wang, Miao-Miao Sun, Ya-Jun He, Shang-Wen Pan, Wei Xiong, Zhe-Kang Peng, Xue-Hui Gao and You Shang. Structure, kinetic properties and biological function of mechanosensitive Piezo channels. Fang *et al. Cell Biosci (2021) 11:13* https://doi.org/10.1186/s13578-020-00522-z

17. TEXTE 134/2020 Umweltforschungsplan des Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit. Forschungskennzahl 3713 53 100 FB000232. Ermittlung und Bewertung tieffrequenter Geräusche in der Umgebung von Wohnbebauung. Abschlussbericht.

18. Evans A. Environmental noise pollution: Has public health become too utilitarian? Open Journal of Social Sciences. 2017;5: 80-107. Available: https: //doi.org/10.4236/jss.2017.55007

19. Krogh, C.M., McMurtry, R.Y., Johnson, W.B., Dumbrille, A., Alves-Pereira, M., Punch, J.L., Hughes, D., Rogers, L., Rand, R.W., James, R., Ambrose, S.E. and Gillis, L. (2021) Grounded Theory as an Analytical Tool to Explore Housing

Decisions Related to Living in the Vicinity of Industrial Wind Turbines. Open Access Library Journal, 8: e7233. https://doi.org/10.4236/oalib.1107233

20. Louisinha A, Oliveira RMJ, Borrecho G, Brito J, Oliveira P, Oliveira da Carvalho A, et al. Infrasound induces coronary perivascular fibrosis in rats. Cardiovascular Pathology. 2018;37: 39-44. Available: https://doi.org/10.1016/j.carpath.2018.10.004

21. Liu Z, Gong L, Li X, et al. Infrasound increases intracellular calcium concentration and induces apoptosis in hippocampi of adult rats. Molecular Medicine Reports. 2012;5: 73-77. Available: https://doi.org/10.3892/mmr.2011.597

22. Pei Z, Chen BY, Tie R, et al. Infrasound exposure induces apoptosis of rat cardiac myocytes by regulating the expression of apoptosis-related proteins. Cardiovascular Toxicology. 2011;11: 341-346. Available: https://doi.org/10.1007/s12012-011-9126-y

23. Zhang MY, Chen C, Xie XJ, et al. Damage to Hippocampus of rats after being exposed to infrasound. Biomedical and Environmental Sciences. 2016;29: 435-442

24. Zhou X, Yang Q, Song F, et al. Tetrahydroxystilbene glucoside ameliorates infrasound-induced central nervous system (CNS) injury by improving antioxidant and anti-inflammatory capacity. Oxidative Medicine and Cellular Longevity. 2020; Article ID: 6576718

25. Chaban R, Ghazy A, Georgiadem E, Stumpf N, Vahl CF. Negative effect of high-level infrasound on human myocardial contractility: *In vitro* Controlled Experiment. Noise Health. 2021;23: 57-66

26. Zhang H, Qi P, Si SY, Ma WM. Effect of infrasound on the growth of colorectal carcinoma in mouse. Chinese Journal of Cancer Prevention and Treatment. 2013; 20:1145-1149

27. Krahé D, Schreckenberg D, Ebner F, Eulitz C, Möhler U. Machbarkeitsstudie zu Wirkungen von Infraschall. Entwicklung von Untersuchungsdesigns für die Ermittlung der Auswirkungen von Infraschall auf den Menschen durch unterschiedliche Quellen. Verlag Umweltbundesamt; 2014 Available: https://www.umweltbundesamt.de/publikationen/machbarkeitsstudie-zu-wirkungenvon-infraschall

28. Stefan Garthe, Henriette Schwemmer, Verena Peschko, Nele Markones, Sabine Müller, Philipp Schwemmer and Moritz Mercker. *Large-scale effects of offshore*

wind farms on seabirds of high conservation concern. **Scientific Reports** (2023) 13:4779 | https://https://doi.org/10.1038/s41598-023-31601-z.

29. Li Gao 1,6, Qingyang Wu, Jixiang Qiu, Yingdan Mei, Yiran Yao, Lina Meng and Pengfei Liu. *The impact of wind energy on plant biomass production in China*. Scientific Reports | (2023) 13:22366 | https://doi.org/10.1038/s41598-023-49650-9.

30. Bellut-Staeck U, Chronic Infrasound Impact is Suspected of Causing Irregular Information via Endothelial Mechano-transduction and Far-reaching Disturbance of Vascular Regulation in All Organisms**.** Chapte**r 5.** Print: ISBN: 978-81-975566-2-3, eBook ISBN: 978-81-975566-5-4. DOI: https://doi.org/10.9734/bpi/mria/v8/727. **Peer-Review History:** This chapter was reviewed by following the Advanced Open Peer Review policy. This chapter was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/727

31. Harding G, Harding P, Wilkins A. Wind turbines, flicker, and photosensitive epilepsy: characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them. Epilepsia. 2008 Jun;49(6):1095-8. doi: 10.1111/j.1528-1167.2008.01563.x. Epub 2008 Apr 4. PMID: 18397297.