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Construction of 50.6 megawatt wind energy development - Roxbury

- Appeal submitted by Rufus Brown on behalf of Concerned Citizens to Save Roxbury
 - Appeal Exhibit K-14

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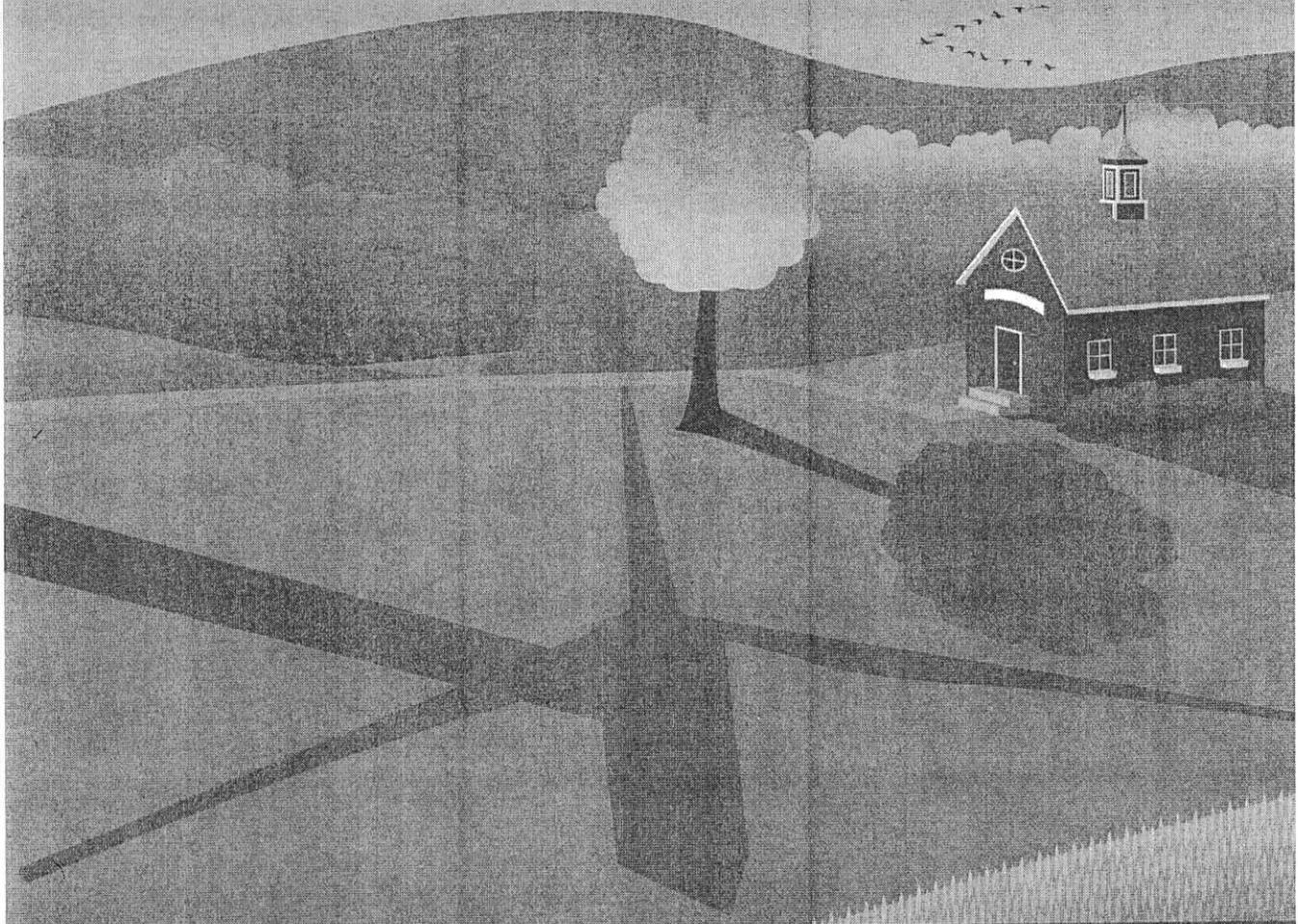
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EXHIBIT
K14

Wind Turbine Syndrome

A Report on a Natural Experiment

March 7, 2009, pre-publication draft



Nina Pierpont, MD, PhD

March 7, 2009, the following is a pre-publication draft, with
pages missing from WTS for Clinicians & Tables

Wind Turbine Syndrome

A REPORT ON A NATURAL EXPERIMENT

Nina Pierpont, MD, PhD

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PREFACE

I wrote this report because I saw a medical problem which few clinicians were paying attention to or, for that matter, seemed to understand. Dr. Amanda Harry in the United Kingdom led the way in recognizing the cluster of symptoms people experience around wind turbines.¹ I, myself, began encountering the problem from numerous e-mails and telephone calls I received, beginning in 2004, shortly after wind developers turned up in my community and my husband and I began investigating industrial wind turbines.

The uniformity of the complaints quickly became apparent. It didn't take long to realize the potential for a relationship between these complaints, on the one hand, and *migraine, motion sickness, vertigo, noise and visual and gastrointestinal sensitivity, and anxiety* which, all together, form a coherent and interconnected neurologic complex in medical practice.

The breakthrough came in early 2006, when I interviewed a couple who were about to move out of their home because of their own and their children's symptoms. The interview supported the relationship between turbine-associated symptoms and migraine/motion sensitivity. Best of all, the interview introduced me to the curious phenomenon of vibration or pulsation felt in the chest. It was this element that piqued the interest of the National Academy of Sciences in its 2007 report to Congress, *Environmental Impacts of Wind-Energy Projects*. The authors wanted to learn more about this effect of low frequency noise.²

This study is my answer to their question.

As I have worked to understand these complaints, I have benefited from new research allowing us to better understand neurologic phenomena like spatial memory loss and fear reactions in people with balance problems—symptoms that often “bored and baffled” clinicians, as one of my referees put it.³ Some wind developers and acousticians are even less charitable.

¹ Harry, Amanda. February 2007. Wind turbines, noise, and health. 32 pp.

http://www.windturbinehealthhumanrights.com/wtnoise_health_2007_a_barry.pdf

² National Research Council. 2007. *Environmental Impacts of Wind-Energy Projects*. The National Academies Press, Washington, DC. 185 pp, p. 109.

³ I review and discuss this research in the *Discussion* section, pp. xx.

It's ... worth noting that studies have shown that a person's attitude toward a sound—meaning whether it's a “wanted” or “unwanted” sound—depends a great deal on what they think and how they feel about the source of the sound. In other words, if someone has a negative attitude to wind turbines, or is worried about them, this will affect how they feel about the sound. However, if someone has a positive attitude toward wind energy, it's very unlikely that the sounds will bother them at all.⁴

Their patients [the people living near wind turbines and reported on by Dr. Osborne and Dr. Harry] may well have been experiencing adverse symptoms, but we have to keep in mind that people who have failed, for whatever reason, in strong objections to a development, build up in themselves a level of unfulfilled expectations and consequent stress, which peaks after the failure and can overload their coping capabilities. This leads them to lay the blame on whatever straw they can clutch. This is especially so in group activities, where mutual support may turn to a mutual, interacting misery, which worsens the situation....The very low levels of low frequency noise and infrasound which occur from wind turbines will not normally cause problems. If problems have occurred, it is possibly for some other stress-related reason.⁵

Brian Howe, a consulting engineer in acoustics for 20 years for HGC Engineering, said Ontario's guidelines for turbine noise are adequate and consistent with Health Canada studies. Most people near wind turbines aren't complaining about the noise, Howe said. In some cases, noise complaints could reflect higher anxiety levels from people who had unrealistic expectations of hearing virtually no sound, he said.⁶

Responses like these are a pity—because they're rubbish. There is nothing “psychosomatic” or malingering about it. Research clearly shows there are precise and definable neurologic connections that explain how sensory signals can derail normal psychological and cognitive function and, in fact, trigger physical symptoms. (It's worth pointing out that our understanding of brain function has progressed by leaps and bounds in the last 25 years, radically changing the landscape of psychology and psychiatry and,

⁴ Noble Environmental Power, LLC. Wind fact sheet #5: Are modern wind turbines noisy?
<http://www.noblepower.com/faqs/documents/06-08-23NEP-SoundFromWindTurbines-FS5-G.pdf>, p. 2.

⁵ Leventhall, Geoff. 2004. Notes on low frequency noise from wind turbines with special reference to the Genesis Power Ltd. Proposal near Waiuku, NZ. Prepared for Genesis Power/Hegley Acoustic Consultants, June 4, p. 7.

⁶ Rennie, Gary. 2009. Wind farm noise limits urged. The Windsor (Ontario, Canada) Star. February 24.

of course, neurology.⁷ Much of the research on vestibular function, whereon I draw heavily, is even more recent, conducted within just the last 10-15 years.)

Leaving that bit of pop psychology behind us, let's move on to evidence-based science. In the world of medicine my study is properly called a "case series," defined as *a descriptive account of a series of individuals with the same new medical problem*. Let me be clear: a case series is a standard and valid form of medical research. New illnesses are often introduced with case series, whose role is to define an illness, suggest causation, and alert the medical and research profession to its existence. (This, simply put, is the purpose of this report.) After an illness is defined and awareness raised, it becomes more feasible to do larger, more expensive studies to explore etiology (causation), pathophysiology, and epidemiologic characteristics.

Case series do not typically have control groups. Nevertheless, I saw I needed a comparison group of similar, though unexposed, people to distinguish which symptoms were due to turbine exposure. The most similar unexposed people, of course, were my study subjects themselves prior to turbine exposure and after the end of exposure. I therefore set up a *before-during-after* study format, interviewing families who had already moved out of their homes due to symptoms, or who were planning to move and had already spent periods away from home during which turbine-associated symptoms abated.

This format served a three-fold purpose:

- 1) it ensured there was an "after" phase for each family
- 2) it guaranteed that at least one member of each family was severely affected, enough to need to move, and
- 3) it provided validation for participant statements, since one can hardly discount the gravity of symptoms that force a family to vacate its home or perform expensive renovations aimed solely at noise exclusion.

Which brings us to what is known in science as a "natural experiment." A natural experiment being a *circumstance wherein subjects are exposed to experimental conditions both inadvertently and ecologically (within their own homes and environments)*. Obviously it would be unethical to expose people deliberately to potentially harmful interventions. Hence natural experiments, while less controlled, have an important role in clarifying the impacts of potentially toxic, man-made exposures.

⁷ See, for example, Schore, Allan N., 1994. *Affect Regulation and the Origin of the Self: The Neurobiology of Emotional Development*. Lawrence Erlbaum Associates, Hillsdale, NJ. 700 pp.

The ecological dimension in the phrase *natural experiment* is worth emphasizing, for the simple reason that many elements of an exposure may not be reproducible in a laboratory, such as round-the-clock exposure, exposure over months, or impacts on customary activities. For symptoms related to wind turbine sound, there are also technical difficulties in reproducing in a laboratory the types of sound, air pressure variation, and vibration that my subjects' observations suggest are involved. Failure to provoke the same symptoms in a laboratory setting may tell us more about the limitations of the laboratory situation than about the real-world effects.

To further create comparison groups, I collected information on all members in the ten families, not just the most affected. This widened the age range of subjects and gave me information on variably affected people who were all exposed to turbine noise capable of causing severe symptoms. I then used the natural variation within the study group to examine which elements of the *pre-exposure* medical history predicted which parts of the *during-exposure* symptom complex. By this method, the study begins to answer the intriguing question of why some individuals are affected more than others by living near wind turbines, and which individuals in the general population are at notable risk for symptoms. It also suggests pathophysiologic mechanisms.

It would be difficult to do a conventional epidemiologic study of the health effects of wind turbines, at least in the United States, even if one were blessed with substantial funding and institutional backing, as I was not. By "epidemiologic" I mean studies in which random or regular sampling is used (as, for example, assessing everyone within three miles of a set of turbines, or every fourth name in an alphabetical listing of everyone within three miles) or case and control populations identified. The difficulty comes from the legal and financial stone wall of the *gag clause*.

In the course of this study I repeatedly encountered these clauses in leases between wind developers and landowners, in "good neighbor" contracts between wind developers and neighbors to leaseholders, and in court decisions following citizen challenges to wind turbine development. Gag clauses prohibit people who receive payments from wind companies, or who have lost legal challenges, from saying anything negative about the turbines or developer. The prohibition includes matters of health. In an epidemiologic study based on interviews or questionnaires these clauses could easily distort answers or skew participation, invalidating a random sample.

Some people informed me, as well, that they didn't want to talk about their problems because they hoped to sell their homes in order to flee the turbines next door. (No better way to kill a real estate deal than to leak the news that one's home is toxic.) There is also the matter of relationships and family ties within small communities, where folks are often reluctant to reveal a problem because, let's say, the turbines on your cousin's land happen to be the source of it.

In this manner has the wind industry both shattered many rural communities and thwarted research like mine.

Despite what I see as the virtues of my approach, this study has clear limitations. One being that it was conducted entirely by clinical interview, over the telephone. This had the benefit of allowing me to have an international group of subjects. On the other hand it limited the type of data I could collect. As a result my ability to say that *a certain symptom during exposure is due to turbines* is confined to medical conditions that are diagnosable by medical history—the medical history being *all the information a patient tells the doctor about his illness, his past health and experiences, and habits*.

Non-clinicians should realize that, in medicine, many conditions (ailments) are diagnosed mostly by *medical history*. This includes migraine and other headaches, tinnitus, and sleep disturbance. For, of course, the doctor cannot tell objectively (by any sort of clinical test) if a patient has headache, tinnitus, or sleep disturbance, and much of what the physician figures out about the causes of these symptoms will come from the other questions he (she) asks of the patient. This is the part I could credibly do by telephone.

My study subjects also told me about other kinds of problems that seemed to worsen during exposure—including asthma, pneumonia, pleurisy, stroke, and changes in coagulation or blood sugar. I did not include these problems in Wind Turbine Syndrome, since my method of study did not allow me to determine whether in fact the wind turbines played a role in these conditions during exposure. These conditions would require other kinds of study over and above the clinical interview and case series. (I have included them in a separate section of the *Results* because I think they may need attention from the medical research community.)

This study also does not tell us how many people are affected within a certain distance of wind turbines. But it does offer a framework for what to pursue in such a study (meaning, the next phase: epidemiologic studies), such as what symptoms to study and what aspects of the exposure to measure.

Shifting, now, to the format of the book. I have written it as a (long) scientific article, beginning with an *Abstract* or brief summary, followed by an *Introduction* to the problem and background information, a description of the *Methods* used (including study sample selection), a presentation of the *Results* (which is the data secured during the study and its analysis), and a *Discussion* of the results with interpretation of their meaning in the context of current medical knowledge.

References are footnoted in the text and listed together at the end. I added a *Glossary* of medical and technical terms to make the book more intelligible to non-medical readers, and a list of *Abbreviations*.

There are two sets of *Tables*. The regular *Tables* (numbered 1 A-C, 2, and 3) are compilations of data found in the *Results* section. What I call the *Family Tables* are the raw narrative data of each individual subject's symptoms and statements, organized one person per table with separate columns for *before*, *during*, and *after* exposure and separate lines for each organ or functional system (e.g., sleep, headache, cognition, balance/equilibrium, ears/hearing, etc.).

The *Family Tables* are presented together at the end of the clinical text. They are the backbone, the substance, of my report. I deeply appreciate my subjects' willingness to be included herein.

The book is intended for physicians and other professionals and individuals who wish to better understand the wind turbine-associated symptom complex. This posed a dilemma: writing in the specialized language of clinical medicine and science is very different from the language one uses for lay readers. Yet my goal is to reach both audiences. I solved the problem by adding (at my editor's insistence) a more conversational, parallel text, which I christened *WTS for Non-Clinicians*.

The result is a book with two, tandem texts. They both say the same thing. One says it in the language of the clinician (*WTS for Clinicians*), the other in the everyday language of—well—my editor (*WTS for Non-Clinicians*).

The goal of *WTS for Clinicians* is scientific precision, including frequent expressions of my degree of certainty or uncertainty. Since the physics and the physiology I invoke are complex and not widely known among clinicians, I explain them in this text. Here, likewise, I quote and summarize numerous scientific articles, and I use numbers and statistics (albeit the simplest type known).

WTS for Non-Clinicians says it all over again, this time in English my mother-in-law would understand. To accomplish this I had to sacrifice a degree of scientific precision, since *plain English* and *scientific precision* don't always mix. I freely acknowledge that *WTS for Non-Clinicians* might set some clinicians' teeth on edge. For this I beg their indulgence.

A second disclaimer. Readers should understand that Wind Turbine Syndrome is not the same as Vibroacoustic Disease.⁸ I say this because the two are often equated in the popular media. The proposed mechanisms are different, and the noise amplitudes are probably different as well. Wind Turbine Syndrome, I propose, is mediated by the vestibular system—by disturbed sensory input to eyes, inner ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person's sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies. Re-stating this, it appears that even low frequency noise or vibration too weak to hear can still stimulate the human vestibular system, opening the door for the symptoms I call Wind Turbine Syndrome. I am happy to report, there is now direct experimental evidence of such vestibular sensitivity in normal humans.⁹

Vibroacoustic Disease, on the other hand, is hypothesized to be caused by direct tissue damage to a variety of organs, creating thickening of supporting structures and other pathological changes.¹⁰ The suspected agent is high amplitude (high power or intensity) low frequency noise. Given my research protocol, described above, my study is of course unable to demonstrate whether wind turbine exposure causes the types of pathologies found in Vibroacoustic Disease, although there are similarities that may be worthy of further clinical investigation, especially with regard to asthma and lower respiratory infections.

Moving on, I have been asked if Wind Turbine Syndrome could be caused by magnetic or electric fields. I have no reason to think so. There has been extensive epidemiologic research since 1979 on magnetic fields and health, comparing people who live close to high power lines or work in electrical utilities or work in other industries where magnetic field exposure is likely to be high, to those who do not.¹¹ This substantial body of research has produced no good evidence that magnetic field exposure causes cancer in

⁸ Castelo Branco NAA, Alves-Pereira M. 2004. Vibroacoustic disease. *Noise Health* 6(23): 3-20.

⁹ Todd NPMc, Rosengren SM, Colebatch JG. 2008. Tuning and sensitivity of the human vestibular system to low-frequency vibration. *Neuroscience Letters* 444: 36-41.

¹⁰ Castelo Branco NAA, Alves-Pereira M. 2004. Vibroacoustic disease. *Noise Health* 6(23): 3-20.

¹¹ Ahlbom IC, Cardis E, Green A, Linet M, Savitz D, Swerdlow A; INCIRP (International Commission for Non-Ionizing Radiation Protection) Standing Committee on Epidemiology. 2001. Review of the epidemiologic literature on EMF and health. *Environ Health Perspect* 109 (Suppl 6): 911-33.

children or adults, cardiac or psychiatric disease, dementia, or multiple sclerosis.^{12,13} After three decades of research, there is still no experimental evidence for a physiologic mechanism for any of the proposed effects of magnetic fields.¹⁴

This makes it very hard to do epidemiologic studies, since researchers don't know what exposure to measure, or what exposure period (e.g., last week or five years ago) might be relevant.¹⁵ An association has been shown between higher magnetic field exposure in utility workers and amyotrophic lateral sclerosis (ALS), a neurodegenerative disease, but this is most likely due to more frequent electric shocks in these settings, not to the magnetic fields.¹⁶ Claims that voltage and frequency irregularities in household alternating currents (what some refer to as "dirty electricity") create a wide, non-specific swath of medical problems – from ADHD to rashes to diabetes to cancer – are completely unsubstantiated, and also have no plausible biologic mechanisms.¹⁷

A few words about peer review. Peer review is quite simple, contrary to the mystique it has acquired among wind developers (most of whom probably have a fanciful idea of what it is). Peer review *consists of sending a scholarly manuscript to experts in that particular field of knowledge, who are asked to judge whether it merits publication.* Simple as that. The identity of reviewers (also called "referees") can be either known to the author (this is often the case with book manuscripts, where authors are routinely asked by the editor to submit a list of possible referees) or kept confidential.

If the referees (usually consisting of two or three) manage to convince the editor that the manuscript is not worthy of publication, the editor contacts the author and rejects the manuscript. If, on the other hand, the referees feel the manuscript merits publication subject to certain revisions and perhaps additions, the editor will forward their reports to the author and ask for a response. "Are you willing to make these changes? Do you agree with these criticisms? If not, give me compelling reasons why not."

The author then revises the manuscript accordingly, except where she feels her referees are wrong—and manages so to convince the editor. Once the editor feels the author has addressed criticisms and suggestions adequately, he (she) proceeds with publication.

¹² Ahlbom IC et al. 2001.

¹³ Johansen C. 2004. Electromagnetic fields and health effects – epidemiologic studies of cancer, diseases of the central nervous system and arrhythmia-related heart disease. Scand J Work Environ Health 30 Suppl 1: 1-30.

¹⁴ Ahlbom IC et al. 2001.

¹⁵ Ahlbom IC et al. 2001.

¹⁶ Johansen C. 2004.

¹⁷ I have asked Prof. Magda Havas, Environmental and Resource Studies, Trent University, Ontario, Canada to remove references to Wind Turbine Syndrome from her PowerPoint presentation on hypothesized wind turbine health effects, because these references are inaccurate.

Lastly, referees do not have to agree with the author's arguments or conclusions. This is worth emphasizing. Their purpose is merely to certify that a) the manuscript conforms to conventional standards of scholarly or clinical research appropriate for the discipline, and, perhaps most important, b) the manuscript is a significant contribution to knowledge.

In the case of this book, a variety of scientists and physicians, all professors at medical schools or university departments of biology, read and commented on the manuscript and recommended it as an important contribution to knowledge and as conforming to the canons of clinical and scientific research. Moreover, they did in fact suggest revisions, even substantial revisions and additions—all of which I made. Some gave me written reports to include in the book itself. Others offered to review the book after it was published.

With that said, the litmus test of scientific validity is not peer review which, after all, is not infallible, as the history of science amply demonstrates. Peer review is an important first step in judging scientific or scholarly merit, however the ultimate test is whether other scientists can follow the author's research protocol and get the same results, or if different lines of research point to the same conclusions.

That, of course, remains to be seen with this report.

I thank Dr. Joel Lehrer in particular for providing me with new information regarding vestibular function, contributions echoed by Drs. Owen Black and Abraham Shulman (all in otolaryngology/neurotology). I thank Professors Ralph Katz (epidemiology) and Henry Horn (ecology) for discussion of scientific method and presentation. Dr. Jerome Haller (neurology) and Professor Robert May (theoretical ecology and epidemiology, past president of the Royal Society of London) read the manuscript and provided commentary to be included in the book, as did Dr. Lehrer and Professors Katz and Horn, for which I am most grateful. Barbara Frey (biomedical librarian) edited the manuscript and provided many essential references.

Other readers read and discussed the manuscript with me and advised on routes of publication. These included Professor Carey Balaban (neuroscience), Dr. Rolf Jacob (psychiatry/ neurotology interface), Dr. John Modlin (pediatrics/infectious diseases), and Dr. Anne Gadomski (pediatrics/public health). I thank them all, as well as Christina Ransom and William McCall, librarians of the Champlain Valley Physician's Hospital in Plattsburgh, NY, and the FYI Hospital Library Circuit Rider Program.

George Kamperman and Rick James, INCE (Institute of Noise Control Engineering) certified noise control engineers, edited the sections describing noise measurement and modeling. They also analyzed noise studies done at the homes of several affected families, while developing standards and protocols for the assessment and control of noise from industrial wind turbines. Kamperman and James presented their standards and rationale at the Noise-Con 2008 meeting of the Institute of Noise Control Engineering (USA) in July 2008, then expanded their paper with a detailed discussion of noise measurement protocols and a model wind turbine ordinance.¹⁸ The expanded paper is posted on the Wind Turbine Syndrome website.¹⁹

Some are surprised that I chose to publish this study as a book rather than an article. My reason is straightforward: it's too long for a medical or scientific journal. The problem is the incompressible yet indispensable narrative data—people's accounts of their sensations, experiences, symptoms, and history. It would be impossible to present these accounts in a 3000 or 7000-word article, yet they are essential as evidence for qualitative changes around turbines.

For example, to support a summary statement like, "The noise from wind turbines has a different and disturbing quality, even when it does not seem loud," I must present the descriptions given by multiple study participants. Likewise, to describe a symptom new to medicine, such as the feeling of internal vibration or pulsation, I again need the words of multiple participants. Because I could not do testing to examine thinking and memory abilities, for example, I need to recount the subjects' own evidence, consisting of their descriptions of things they used to do easily but now cannot do, or of loss and recovery in their children's school functioning.

Many of my reviewers suggested ways to split the study into shorter papers—a segment on migraine, a segment on tinnitus, a segment on methodology, for example. However, I feel that keeping the entire study in one piece makes for a more powerful and intelligible document, allowing readers to appreciate the intertwined nature of individual symptoms and the way they fit with new neural models of vestibular function.

As for the reception I anticipate for this report, I don't flatter myself that it will be greeted with loud hosannas from the wind industry. Keep in mind that wind developers have what is called in science a

¹⁸ Kamperman GW, James RR, Simple guidelines for siting wind turbines to prevent health risks. Noise-Con, July 28-31, 2008, Institute of Noise Control Engineering/USA.

¹⁹ See "How loud is too loud?" www.windturbinesyndrome.com.

“conflict of interest.” Meaning, their judgment is unduly influenced by money. “It’s difficult to get a man to understand something when his salary depends upon his not understanding it,” wryly observed Upton Sinclair.²⁰

I have no conflicts of interest. This research was unfunded, and neither my small village property, my town, nor the Adirondack Park bordering my town is a likely candidate for a wind farm. Is a fondness for bats and other interesting, highly evolved animals a conflict of interest? I wouldn’t think so. Admittedly, I am distressed to hear about bats dying of internal hemorrhage as they fly near wind turbines,²¹ just as I am distressed to hear that people are forced from their homes or endure cognitive impairment of uncertain reversibility in order to remain in the only home they can afford. I have spoken and written earnestly and vigorously about wind developers because of their stubborn refusal to acknowledge health problems amply documented in this and other studies.²² Such stonewalling would test the patience of a saint—and I am no saint.

My hope is that this report will balance the risk-benefit picture of wind turbines more realistically, and help those individuals, such as George Kamperman and Rick James, who are actively promoting noise control criteria that will prevent the health and home abandonment problems documented here.

Kamperman and James have convinced me that a single, one-size-fits-all setback distance may not be both protective and fair in all environments with all types of turbines. Even so, it is clear from this study and others that minimum protective distances need to be:

- a) greater than the 1-1.5 km. (3280-4900 ft. or 0.62-0.93 mi.) at which there were severely affected subjects in this study
- b) greater than the 1.6 km. (5250 ft. or 1 mi.) at which there were affected subjects in Dr. Harry’s UK study
- c) and, in mountainous terrain, greater than the 2-3.5 km. (1.24-2.2 mi.) at which there were symptomatic subjects in Professor Robyn Phipps’s New Zealand study.²³

²⁰ Sinclair, Upton. 1935. *I, Candidate for Governor: And How I Got Licked*.

²¹ Baerwald EF, D’Amours GH, Klug BJ, Barclay RM. 2008. Barotrauma is a significant cause of bat fatalities at wind turbines. *Curr Biol* 18(16): R695-6. Due to air pressure shifts near moving turbine blades, blood vessels in bats’ lungs and abdomen are disrupted, which produces fatal internal hemorrhage.

²² In anticipation of wind industry blowback, I imagine it may once again publicize that it thinks *I think* wind turbines cause mad cow disease. I do not and never did. My reply to this canard – now a family joke – was published several years ago (www.windturbinesyndrome.com/?p=84). My previous reports and papers on Wind Turbine Syndrome and the wind industry can be found on www.windturbinesyndrome.com.

²³ See *Introduction*, p. x, for discussion and references.

Two kilometers, or 1.24 miles, remains the baseline, shortest setback from residences (and hospitals, schools, nursing homes, etc.) that communities should consider. In mountainous terrain, 2 miles (3.2 km) is probably a better guideline. Setbacks may well need to be longer than these minima, as guided by the noise criteria developed by Kamperman and James.

The shorter setbacks currently in use in the USA and elsewhere—1000 to 1500 ft. (305-457 m.)—are a convenience and financial advantage for wind developers and participating landowners. They have no basis in research on safety and health, and they do not make clinical sense.

For those who read this report and recognize their own symptoms, the appropriate medical specialist to consult would be a neurologist (or otoneurologist), who is an otolaryngologist (ears, nose, and throat doctor) who specializes in balance, the inner ear, and its neurological connections. When I sent this report out for critical review, these were the physicians who recognized a remarkably similar symptom complex from cases familiar to them—such as certain inner ear pathologies.

To those of you living near turbines and recognizing your own symptoms within these pages: you are not crazy and not fabricating them. Your symptoms are clinically valid—and unnecessary. While wind developers rush headlong into yet more projects, you unfortunates will have to exercise patience as the medical profession catches up with what is ailing you. Meanwhile, my advice is: speak out. In *The Tyranny of Noise*, Robert Alex Baron calls for an end to “our passive acceptance of industry's acoustic waste products.”²⁴

This will happen only when the suffering refuse to be silenced.

By the time I finished interviewing (February 2008) and moved on to data analysis, six of the ten families in this study had moved out of their homes because of turbine-associated symptoms. Three months later (May 2008), when the first draft was complete and I contacted the families for their approval and permission to publish the information about them, two more had moved out because of their turbine-associated symptoms—bringing the total to eight of the ten. The ninth family could not afford to move, but had done extensive renovations in an effort to keep the noise out. (Renovations, ironically, that made the house worse to live in, since they could no longer heat it properly.) As of this writing, family number ten is struggling to remain in their home.

²⁴ Baron, Robert Alex. 1970. *The Tyranny of Noise: The World's Most Prevalent Pollution, Who Causes It, How It's Hurting You, and How to Fight It*. St. Martin's Press, New York, p. 12.

Behold ten families whose lives have been turned upside down because of the wind industry's acoustic waste products.

Finally, ask yourself why a country doctor practicing in the poorest county in New York State did this study, and not the Centers for Disease Control or some other relevant government agency. It's a fair question and a troubling one. I ask it myself.

It is well known that wind developers target impoverished communities for their wind farms. This explains the "poorest county" part of my question, and likewise why wind turbines quickly became a looming issue in my life four years ago. But it leaves unanswered the part about, Why did I write this report, and not the government?

To answer that would of necessity catapult this report (and me) into the treacherous territory of public policy. One would like to think science is not beholden (craven?) to public policy, but that would be naïve, would it not? Moreover, while the scientist in me would like to imagine that I can write this report and remain above the hurly burly of public policy, I know this, too, is naïve. Wind Turbine Syndrome is an industrial plague. It is man-made and easily fixed. Proper setbacks are the best cure I know of; they do the job just fine. If I could scrawl this on a prescription pad and hand it to my subjects in this report, I would do so. No brilliant scientist needs to discover a new antibiotic or vaccine or sleeping pill to treat it.

Setbacks, however, are not considered matters of public health, but matters of public policy—what is called "politics." And right there is the rub. In the global rush to wind energy there is almost no voice heard for public health repercussions. Where it is heard—at town meetings, on the Internet, in Letters to the Editor, in courtrooms—it is routinely ridiculed. I speak from experience.

Wind energy is being promoted by every state and national government I know of, under intense pressure (lobbying) by wind development companies generally owned or otherwise capitalized by powerful investment banks which in turn take large tax write-offs and reap large government subsidies for their wind farm projects. These companies then turn around and sell carbon credits (green credits). Perhaps this helps explain why no provision is made for clinical caution?

And perhaps this goes some way toward explaining why a pediatrician in rural NYS and a general practitioner in Cornwall, England—along with a handful of rank-and-file physicians elsewhere in the UK and Australia and who knows where else—are the ones funding this research and writing these reports.

Then so be it.

Nina Pierpont, MD, PhD
Malone, NY
Winter 2009

Draft

Wind Turbine Syndrome for Clinicians

Abstract

This report documents a consistent and often debilitating complex of symptoms experienced by adults and children while living near large industrial wind turbines (1.5-3 MW). It examines patterns of individual susceptibility and proposes pathophysiologic mechanisms. Symptoms include sleep disturbance, headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering that arise while awake or asleep.

The study is a case series of 10 affected families, with 38 members age <1 to 75, living 305 m to 1.5 km (1000 to 4900 ft) from wind turbines erected since 2004. All competent and available adults and older teens completed a detailed clinical interview about their own and their children's symptoms, sensations, and medical conditions (a) before turbines were erected near their homes, (b) while living near operating turbines, and (c) after leaving their homes or spending a prolonged period away.

Statistically significant risk factors for symptoms during exposure include pre-existing migraine disorder, motion sensitivity, or inner ear damage (pre-existing tinnitus, hearing loss, or industrial noise exposure). Symptoms are not statistically associated with pre-existing anxiety or other mental health disorders. The symptom complex resembles syndromes caused by vestibular dysfunction. People without known risk factors are also affected.

The proposed pathophysiology posits disturbance to balance and position sense when low frequency noise or vibration stimulates receptors for the balance system (vestibular, somatosensory, or visceral sensory, as well as visual stimulation from moving shadows) in a discordant fashion. Vestibular neural signals are known to affect a variety of brain areas and functions, including spatial awareness, spatial memory, spatial problem-solving, fear, anxiety, autonomic functions, and aversive learning, providing a robust neural framework for the symptom associations in Wind Turbine Syndrome. Further research is needed to prove causes and physiologic mechanisms, establish prevalence, and to explore effects in special populations, including children. This and other studies suggest that safe setbacks will be at least 2 km (1.24 mi), and will be longer for larger turbines and in more varied topography.

Introduction and background

Policy initiatives in the United States and abroad currently encourage the construction of extremely large wind-powered electric generation plants (wind turbines) in rural areas. In its current format, wind electric generation is a variably regulated, multi-billion dollar a year industry. Wind turbines are now commonly placed close to homes. Usual setbacks in New York State, for example, are 305-457 m (1000-1500 ft) from houses.¹ Developer statements and preconstruction modeling lead communities to believe that disturbances from noise and vibration will be negligible or nonexistent.^{2,3,4} Developers assure prospective communities that turbines are no louder than a refrigerator, a library reading room, or the rustling of tree leaves which, they say, easily obscures turbine noise.⁵

Despite these assurances, some people experience significant symptoms after wind turbines are placed in operation near their homes. The purpose of this study is to establish a case definition for the consistent, frequently debilitating, set of symptoms experienced by people while living near wind turbine installations, and to place this symptom complex within the context of known pathophysiology. A case definition is needed to allow studies of causation, epidemiology, and outcomes to go forward, and to establish adequate community controls.

¹ Town of Ellenburg, NY wind law—1000 ft (305 m); Town of Clinton, NY wind law—1200 ft (366 m); Town of Martinsburg, NY wind law—1500 ft (457 m). For other examples in and outside NY State, see *Wind Energy Development: A Guide for Local Authorities in New York*, New York State Energy Research and Development Authority, October 2002, p. 27. <http://text.nyserda.org/programs/pdfs/windguide.pdf>

² "The GE 1.5 MW wind turbine, which is in use in Fenner, New York, is generally no louder than 50 decibels (dBA) at a distance of 1,000 feet (the closest we would propose siting a turbine to a residence). Governmental and scientific agencies have described 50 dBA as being equivalent to a 'quiet room.' Please keep in mind that these turbines only turn when the wind blows, and the sound of the wind itself is often louder than 50 dBA. Our own experience, and that of many others who live near or have visited the Fenner windfarm, is that the turbines can only be heard when it is otherwise dead quiet, and even then it is very faint, especially at a distance." Letter from Noble Environmental Power, LLC, to residents of Churubusco (Town of Clinton), New York, 7/31/2005.

³ "Virtually everything with moving parts will make some sound, and wind turbines are no exception. However, well-designed wind turbines are generally quiet in operation, and compared to the noise of road traffic, trains, aircraft, and construction activities, to name but a few, the noise from wind turbines is very low... Today, an operating wind farm at a distance of 750 to 1,000 feet is no noisier than a kitchen refrigerator or a moderately quiet room." *Facts about wind energy and noise*. American Wind Energy Association, August 2008, p. 2. http://www.awea.org/pubs/factsheets/WE_Noise.pdf

⁴ "In general, wind plants are not noisy, and wind is a good neighbor. Complaints about noise from wind projects are rare, and can usually be satisfactorily resolved." *Facts about wind energy and noise*. American Wind Energy Association, August 2008, p. 4. http://www.awea.org/pubs/factsheets/WE_Noise.pdf

⁵ "Outside the nearest houses, which are at least 300 metres away, and more often further, the sound of a wind turbine generating electricity is likely to be about the same level as noise from a flowing stream about 50-100 metres away or the noise of leaves rustling in a gentle breeze. This is similar to the sound level inside a typical living room with a gas fire switched on, or the reading room of a library or in an unoccupied, quiet, air-conditioned office... Even when the wind speed increases, it is difficult to detect any increase in turbine sound above the increase in normal background sound, such as the noise the wind itself makes and the rustling of trees." *Noise from wind turbines: the facts*. British Wind Energy Association, August 2008. <http://www.bwea.com/ref/noise.html>

This set of symptoms stands out in the context of noise control practice. George Kamperman, P.E., INCE Bd. Cert., past member of the acoustics firm Bolt, Beranek and Newman (USA), wrote, "After the first day of digging into the wind turbine noise impact problems in different countries, it became clear that people living within about two miles from 'wind farms' all had similar complaints and health problems. I have never seen this type of phenomenon [in] over fifty plus years of consulting on industrial noise problems. The magnitude of the impact is far above anything I have seen before at such relatively low sound levels. I can see the devastating health impact from wind turbine noise but I can only comment on the physical noise exposure. From my viewpoint we desperately need noise exposure level criteria."⁶

I named this complex of symptoms "Wind Turbine Syndrome" in a preliminary fashion in testimony before the Energy Committee of the New York State Legislature on March 7, 2006. My observation that people can feel vibration or pulsations from wind turbines, and find it disturbing, was quoted in the brief section "Impacts on Human Health and Well-Being" in the report *Environmental Impacts of Wind-Energy Projects* of the National Academy of Science, published in May 2007. No other medical information was cited in this report. The authors asked for more information to better understand these effects.⁷

Debates about wind turbine-associated health problems have been dominated to date by noise control engineers, or acousticians, which is problematic in part because the acoustics field at present is dominated by the wind turbine industry,⁸ and in part because acousticians are not trained in medicine. A typical approach to wind turbine disturbance complaints, world-wide, is *noise first, symptoms second*: if an acoustician can demonstrate with noise measurements that there is no noise considered significant in a setting, then the symptoms experienced by people in that setting can be, and frequently are, dismissed. This has been the experience of seven of the ten families in this study in the United States, Canada,

⁶ George Kamperman, personal communication, 2/21/2008. See <http://www.kamperman.com/index.htm>

⁷ National Research Council. 2007. *Environmental Impacts of Wind-Energy Projects*. The National Academies Press, Washington, DC. 185 pp, p. 109.

⁸ George Kamperman, personal communication, 2/23/2008.

Ireland, and Italy.⁹ At least one developer has put forward the hypothesis that a negative attitude or worry towards turbines is what leads people to be disturbed by turbine noise.¹⁰

A reorientation is in order. If people are so disturbed by their headaches, tinnitus, sleeplessness, panic episodes, disrupted children, or memory deficits that they must move or abandon their homes to get away from wind turbine noise and vibration, then that noise and vibration is by definition significant, because the symptoms it causes are significant. The role of an ethical acoustician is to figure out what type and intensity of noise or vibration creates particular symptoms, and to propose effective control measures.

My study subjects make it clear that their problems are caused by noise and vibration. Some symptoms in some subjects are also triggered by moving blade shadows. However, I do not present or analyze noise data in this study, because noise is not my training. (Conversely, symptoms and disease are not the training of acousticians.) I focus on detailed symptomatic descriptions and statistical evaluation of medical susceptibility factors within the study group. Correlating the noise and vibration characteristics of the turbine-exposed homes with the symptoms of the people in the homes is an area ripe for collaboration between medical researchers and independent noise control engineers.

Other than articles on the Internet, there is currently no published research on wind turbine-associated symptoms. A UK physician, Dr. Amanda Harry, whose practice includes patients living near wind turbines, has published online the results of a checklist survey, documenting specific symptoms among 42 adults who identified themselves to her as having problems while living 300 m to 1.6 km (984 ft to 1 mi) from turbines.¹¹ She found a high prevalence of sleep disturbance, fatigue, headache, migraine, anxiety,

⁹A notable exception to this pattern is the work of GP van den Berg, PhD, who, as a graduate student and a member of the Science Shop for Physics of the University of Groningen in the Netherlands, investigated noise complaints near a wind turbine park and devised new models of atmospheric noise propagation to fit the phenomena he observed. References: 1) van den Berg, GP. 2004. Effects of the wind profile at night on wind turbine sound. *Journal of Sound and Vibration* 277: 955-970; 2) van den Berg, GP. 2004. Do wind turbines produce significant low frequency sound levels? 11th International Meeting on Low Frequency Noise and Vibration and Its Control, Maastricht, The Netherlands, 30 August to 1 September 2004, 8 pp.; 3) van den Berg, GP. 2005. The beat is getting stronger: the effect of atmospheric stability on low frequency modulated sound of wind turbines. *Journal of Low Frequency Noise, Vibration, and Active Control*, 24(1): 1-24; 4) van den Berg, GP. 2006. The sound of high winds: the effect of atmospheric stability on wind turbine sound and microphone noise. PhD dissertation, University of Groningen, The Netherlands. 177 pp. <http://irs.ub.rug.nl/ppn/294294104>

¹⁰"We often use the word 'noise' to refer to 'any unwanted sound.' It's true that wind turbines make sounds... but whether or not those sounds are 'noisy' has a lot to do with who's listening. It's also worth noting that studies have shown [no references provided in source document] that a person's attitude toward a sound – meaning whether it's not 'wanted' or 'unwanted' sound – depends a great deal on what they think and how they feel about the source of the sound. In other words, if someone has a negative attitude to wind turbines, or is worried about them, this will affect how they feel about the sound. However, if someone has a positive attitude toward wind energy, it's very unlikely that the sounds will bother them at all." *Wind fact sheet #5: Are modern wind turbines noisy?* Noble Environmental Power, LLC, <http://www.noblepower.com/faqs/documents/06-08-23NEP-SoundFromWindTurbines-FS5-G.pdf>, p. 2.

¹¹ Harry, Amanda. February 2007. Wind turbines, noise, and health. 32 pp. http://www.windturbinehealthhumanrights.com/wtnoise_health_2007_a_barry.pdf

depression, tinnitus, hearing loss, and palpitations. Respondents described a similar set of symptoms and many of the same experiences that I document in this report, including having to move out of their homes because of symptoms. Respondents were mostly older adults: 42% were age 60 or older, 40% age 45-60, 12% age 30-45, and 5% age 18-30. A biomedical librarian, Barbara Frey, working with this physician and others, has published online a compilation of other personal accounts of symptoms and sensations near wind turbines.¹² These also mirror what I document.

Robyn Phipps, PhD, a New Zealand scientist specializing in health in indoor environments, systematically surveyed residents up to 15 km (9.3 mi) from operating wind turbine installations, asking both positive and negative questions about visual, noise, and vibration experiences.¹³ All respondents (614 or 56% of the 1100 households to whom surveys were mailed) lived at least 2 km (1.24 mi) from turbines, with 85% of respondents living 2-3.5 km (1.24-2.2 mi) from turbines and 15% farther away. Among other questions, the survey asked about unpleasant physical sensations from turbine noise, which were experienced by 2.1% of respondents, even at these distances. Forty-one respondents (6.7%) spontaneously telephoned Dr. Phipps to tell her more than was asked on the survey about their distress due to turbine noise and vibration, nearly all (39) with disturbed sleep.¹⁴ Symptoms were not further differentiated in this study, but clearly may occur at distances even greater than 2 km (1.24 mi) from turbines.

Published survey studies have examined residents' reactions to wind turbines relative to modeled noise levels and visibility of turbines in Sweden^{15,16,17} and the Netherlands.^{18,19,20} The study in the Netherlands included questions on health and stress (see below, *Discussion*). Both sets of studies, the Swedish and

¹² Frey, Barbara J and Hadden, Peter J. February 2007. Noise radiation from wind turbines installed near homes: effects on health. 137 pp. http://www.windturbinehealthhumanrights.com/wtnhhr_june2007.pdf

¹³ Phipps, Robyn. 2007. Evidence of Dr. Robyn Phipps, in the matter of Moturimu wind farm application, heard before the Joint Commissioners 8th-26th March 2007, Palmerston North [New Zealand]. 43 pp.

<http://www.wind-watch.org/documents/wp-content/uploads/hipps-moturimutestimony.v.pdf>

¹⁴ Phipps 2007

¹⁵ Pedersen E, Persson Waye K. 2004. Perceptions and annoyance due to wind turbine noise – a dose-response relationship. *J Acoust Soc Am* 116(6): 3460-70.

¹⁶ Pedersen E. 2007. Human response to wind turbine noise: perception, annoyance and moderating factors. Dissertation, Occupational and Environmental Medicine, Department of Public Health and Community Medicine, Goteborg University, Goteborg, Sweden. 86 pp.

¹⁷ Pedersen E, Persson Waye K. 2007. Wind turbine noise, annoyance and self-reported health and wellbeing in different living environments. *Occup Environ Med* 64(7): 480-6.

¹⁸ Pedersen E, Bouma J, Bakker R, van den Berg GP. 2008. Response to wind turbine noise in the Netherlands. *J Acoust Soc Am* 123(5): 3536 (abstract).

¹⁹ van den Berg GP, Pedersen E, Bakker R, Bouma J. 2008. Wind farm aural and visual impact in the Netherlands. *J Acoust Soc Am* 123(5): 3682 (abstract).

²⁰ van den Berg GP, Pedersen E, Bouma J, Bakker R. 2008. Project WINDFARMperception: visual and acoustic impact of wind turbine farms on residents. Final report, June 3, 2008. 63 pp. Summary:

<http://umcg.wewi.eldoc.ub.rug.nl/FILES/root/Rapporten/2008/WINDFARMperception/WFp-final-summary.pdf>

Entire report: <https://dSPACE.hh.se/dspace/bitstream/2082/2176/1/WFp-final.pdf>

Dutch, make important contributions to the rational setting of noise limits near wind turbines (see *Discussion*).

With regard to official opinion, the National Academy of Medicine in France recommended in 2005 that industrial wind turbines be sited at least 1.5 km (0.93 mi) from human habitation due to health effects of low frequency noise produced by the turbines.²¹

Current wind turbines have three airfoil-shaped rotor blades attached by a hub to gears and a generator, which are housed in a bus-sized box (nacelle) at the top of a nearly cylindrical, hollow steel tower. The nacelle is rotated mechanically to face the blades into the wind. The blades spin upwind of the tower. The tower is anchored in a steel-reinforced concrete foundation. Turbines heights in this study were 100 to 135 m (328 to 443 ft) with hub heights 59 to 90 m (194 to 295 ft) and blade lengths 33 to 45 m (108 to 148 ft). Individual turbine powers were 1.5 to 3 MW. Clusters contained from 8 to 45 individual turbines (see Table 1B).

In this study, participants from all families described good and bad symptomatic periods correlated with particular sounds from the turbine installations, rate of turbine spin, or whether the turbines were turned towards, away from, or sideways relative to their homes. All participants identified wind directions and intensities that exacerbated their problems and others that brought relief. Many subjects described a quality of invasiveness in wind turbine noise, more disturbing than other noises like trains. Some stated that the noise wouldn't sound loud to people who did not live with it, or that noises described with benign-sounding terms like "swish" or "hum" were in reality very disturbing. Several were disturbed specifically by shadow flicker, which is the flashing of light in a room as the slanting sun shines through moving turbine blades, or the repetitive movement of the shadows across yards and walls. (These observations are documented in the individual accounts in the *Family Tables*.)

Wind turbines generate sound across the spectrum from the infrasonic to the ultrasonic,²² and also produce ground-born or seismic vibration.²³ "In the broadest sense, a sound wave is any disturbance that is propagated in an elastic medium, which may be a gas, a liquid, or a solid. Ultrasonic, sonic, and infrasonic waves are included in this definition... Sonic waves [are] those waves that can be perceived by

²¹ Le retentissement du fonctionnement des éoliennes sur la santé de l'homme, le Rapport, ses Annexes et les Recommandations de l'Académie nationale de médecine, 3/14/2006. 17 pp.

http://www.academie-medicine.fr/sites_thematiques/EOLIENNES/chouard_rapp_14mars_2006.htm

²² van den Berg 2004

²³ Style, P, Stimpson I, Toon S, England R, and Wright M. 2005. Microseismic and infrasound monitoring of low frequency noise and vibrations from wind farms. Recommendations on the siting of wind farms in the vicinity of Eskdalemuir, Scotland. 125 pp. http://www.esci.keele.ac.uk/geophysics/News/windfarm_monitoring.html

the hearing sense of the human being. Noise is defined as any perceived sound that is objectionable to a human being."²⁴

Following the usual usage in noise literature, I use the word *vibration* to refer to disturbances in solid media, such as the ground, house structures, or the human body. When air-borne sound waves of particular energy (power) and frequency meet a solid object, they may set the object vibrating. Conversely, a vibrating solid object, such as the strings on a violin, can create sound waves in air. There is energy transfer in both directions between air-borne or fluid-borne sound waves and the vibration of solids. When I talk about noise and vibration together, I am referring to this continuum of mechanical energy in the air and in solids.

Energy in either form (sound or vibration) can impinge on the human body, and there may be multiple exchanges between air and solids in the path between a source and a human. The tissues of humans and other animals are semi-liquid to varying degrees, and have fluid-filled and air-filled spaces within them, as well as solid structures like bones. As an example of such energy transfer, a sound wave in the air, encountering a house, may set up vibrations in the structure of the house. These vibrations, in walls or windows, may set up air pressure (sound) waves in rooms, which in turn can transmit mechanical energy to the tympanic membrane and middle ear, to the airways and lungs, and to body surfaces. Alternatively, vibrations in house structures or the ground may transmit energy directly to the body by solid-to-solid contact and be conducted through the body by bone conduction.

All parts of the body (and indeed all objects) have specific resonance frequencies, meaning *particular frequencies or wavelengths of sound will be amplified in that body part.*²⁵ If the wavelength of a sound or its harmonic matches the dimensions of a room, it may set up standing waves in the room with locations where the intersecting, reverberating sound waves reinforce each other. Resonance also occurs inside air-filled body cavities such as the lungs, trachea, pharynx, middle ear, mastoid, and gastrointestinal tract. The elasticity of the walls and density of the contents of these spaces affect the dynamics of sound waves inside them. The orbits (bones surrounding the eyes) and cranial vault (braincase) are also resonance chambers, because of the lower density of their contents compared to the bones that surround them. There are also vibratory resonance patterns along the spine (which is elastic), including a resonance

²⁴ Beranek, LL. 2006. Basic acoustical quantities: levels and decibels. Chapter 1 in Ver IL, Beranek LL, *Noise and Vibration Control and Engineering: Principles and Applications*. John Wiley and Sons, Hoboken, NJ. 976 pp., p. 1.

²⁵ Hedge, Alan, Professor, Cornell University, Department of Design and Environmental Analysis, syllabus/lecture notes for DEA 350: Whole-Body Vibration, January 2007, found at <http://ergo.human.cornell.edu/studentdownloads/DEA325pdfs/Human%20Vibration.pdf>

involving the movement of the head relative to the shoulders. Von Gierke^{26,27} and Rasmussen²⁸ have described the resonant frequencies of different parts of the human body.

Noise intensity is measured in decibels (dB), a logarithmic scale of sound pressure amplitude. Single noise measurements or integrated measurements over time combine the energies of a range of frequencies into a single number, as defined by the filter or weighting network used during the measurement. The A weighting network is the most common in studies of community noise. It is designed to duplicate the frequency response of human hearing. A-weighting augments the contributions of sounds in the 1000 to 6000 Hz range (from C two octaves above middle C, key 64 on the piano, to F# above the highest note on the piano), and progressively reduces the contributions of lower frequencies below about 800 Hz (G-G# 1½ octaves above middle C, keys 59-60). At 100 Hz, where the human inner ear vestibular organ has a peak response to vibration²⁹ (G-G# 1½ octaves below middle C, keys 23-24), A-weighting reduces measurement by a factor of 1000 (30 dB). At 31 Hz (B, the second-to-bottom white key, key 3), A-weighting reduces sound measurement by a factor of 10,000 (40 dB). Thus A-weighting preferentially captures the high sounds used in language recognition, to which the human cochlea is indeed very sensitive, but reduces the contribution of mid- and lower-range audible sounds, as well as infrasound (defined as 20 Hz and below).

Linear (lin) measurements use no weighting network, so the frequency responses are limited by other aspects of the system, such as microphone sensitivity. Linear measurements may capture low-frequency sounds but are not standardized – different sound level meters yield different results. As a result, the standardized and commonly available C weighting network is preferred for measuring environmental noise with low-frequency components, such as noise from wind turbines. The C weighting network has a flat response (meaning that it does not reduce or enhance the contributions of different frequencies) over the audible frequency range and a well-defined decreasing response below 31 Hz.

One third (1/3) octave band studies are used to describe sound pressure levels by frequency, and are presented as a graph rather than a single number. One third (1/3) octave bands can also be measured linearly or with weighting networks.

²⁶ von Gierke HE, Parker DE. 1994. Differences in otolith and abdominal viscera graviceptor dynamics: implications for motion sickness and perceived body position. *Aviat Space Environ Med* 65(8): 747-51.

²⁷ von Gierke HE. 1971. Biodynamic models and their applications. *J Acoust Soc Am* 50(6): 1397-413.

²⁸ Rasmussen G. 1982. Human body vibration exposure and its measurement. *Bruel and Kjaer Technical Paper No. 1*, Naerum, Denmark. Abstract: Rasmussen G. 1983. Human body vibration exposure and its measurement. *J Acoust Soc Am* 73(6): 2229.

²⁹ Todd NPMc, Rosengren SM, Colebatch JG. 2008. Tuning and sensitivity of the human vestibular system to low-frequency vibration. *Neuroscience Letters* 444: 36-41.

telephone about further developments. All ten families have reviewed the information presented about them and signed permission for anonymous publication.

I use simple statistical tests ($2 \times 2 \chi^2$) to examine associations among symptoms and between pre-existing conditions and symptoms during exposure.³¹ Degrees of freedom (df) is 2 for all the χ^2 results in this report. Children were excluded from the analysis of adult symptoms if no child younger than a certain age had the symptom in question. Study children were categorized into developmental-age blocks (see Table 1C). When I excluded children from an analysis, I excluded all the children in that age block and below. Excluding children from adult symptom analyses avoided inflating the no symptom/absent pre-existing condition box of the $2 \times 2 \chi^2$ contingency tables, which could artificially increase the χ^2 value.

Results

I interviewed 23 adult and teenage members of 10 families, collecting information on all 38 adult, teen, and child family members. One family member was a baby born a few days before the family (A) moved out, so there is no data for this child on sleep or behavior during exposure (which was in utero). Thus the sample size of subjects for whom we have information about experiences or behavior during exposure is 37.

Residence status and family composition are detailed in Table 1A; turbine, terrain, and house characteristics in Table 1B; and the age and sex distribution of subjects in Table 1C. Twenty subjects were male and 18 female, ranging in age from <1 to 75. Seventeen subjects were age 21 and below, and 21 subjects were age 32 and above. There is a gap in the 20's and a preponderance of subjects in their 50's. Wind turbine brands to which study subjects were exposed included Gamesa, General Electric, Repower, Bonus (Siemens), and Vestas.

Individual accounts of baseline health status and pre-exposure, during exposure, and post-exposure symptoms or absence of symptoms are presented in Family Tables A through J, with a separate sub-table for each individual. I encourage the reader to read these, because they highlight the before-during-after comparisons for each person, show how the symptoms fit together for individuals, reveal family patterns, and provide subjects' own words for what they feel and detect. When individuals are referred to in the

³¹ Sokal RR, Rohlf FJ. 1969. *Biometry*. WH Freeman and Co., San Francisco. 776 pp.

text, the letter and number in parentheses (e.g., A1, C2) refers to the family sub-table in which that subject's information is found.

Baseline conditions

Eight adult subjects had serious baseline medical conditions, including lupus (1), breast cancer (2), diabetes (1), coronary artery disease (2), hypertension (1), atrial fibrillation with anticoagulation (1), Parkinson's disease (1), ulcer (1), and fibromyalgia (2). Two were male (age 56-64) and six female (age 51-75). Other baseline medical conditions are listed in Table 2. Four subjects smoked at the beginning of exposure, and five others had smoked in the past (Table 2). There were no seriously ill children in the sample.

Seven subjects had histories of mental health disorders including depression, anxiety, post-traumatic stress disorder (PTSD), and bipolar disorder. Three were male (age 42-56) and four female (age 32-64). One of these men (age 56) also had Alzheimer's disease. There were no children with mental health disorders or developmental disabilities in this sample.

Eight subjects had pre-existing migraine disorder (including two with previous severe sporadic headaches that I interpreted as migraine). Four were male (age 19-42) and four female (age 12-42). An additional seven subjects, age <1 to 17, were children of migraineurs who had not experienced migraines themselves at baseline.

Eight subjects had permanent hearing impairments, defined subjectively or objectively, including mild losses, losses limited to one ear, or impairments of binaural processing. Six were male (age 32-64) and two female (age 51-57).

Six subjects had continuous tinnitus or a history of multiple, discrete episodes of tinnitus prior to exposure. Four were male (age 19-64) and two female (age 33-57).

Twelve subjects had significant previous noise exposure, defined as working in noisy industrial or construction settings; working on or in a diesel boat, truck, bus, farm equipment, or aircraft; a military tour of duty; or operating lawn mowers and chain saws for work. Not included were home or sporadic use of lawn mowers and chain saws, commuting by train or airplane, urban living in general, or playing or

listening to music. Nine of the noise-exposed subjects were male (age 19-64) and three female (age 33-53).

Eighteen subjects were known to be motion sensitive prior to exposure, as defined by carsickness as a child or adult, any episode of seasickness, or a history of two or more episodes of vertigo. Ten were male (age 6-64) and eight female (age 12-57).

Seven subjects had a remembered history of a single concussion, and none had a history of a more severe head injury. Six were male (age 19-59) and one female (age 12). I did not collect information on whiplash injury.

Core symptoms

Core symptoms are defined as 1) common and widely described by study participants, 2) closely linked in time and space to turbine exposure, and 3) amenable to diagnosis by medical history. Core symptoms include sleep disturbance, headache, tinnitus, other ear and hearing sensations, disturbances to balance and equilibrium, nausea, anxiety, irritability, energy loss, motivation loss, and disturbances to memory and concentration.

An additional core symptom is a new type of internal or visceral sensation which has no name in the medical lexicon. Subjects struggled to explain these sensations, often apologizing for how strange their words sounded. A physician subject called it "feeling jittery inside" or "internal quivering." Other subjects chose similar words, while others talked about feeling pulsation or beating inside. The physical sensations of quivering, jitteriness, or pulsation are accompanied by acute anxiety, fearfulness, or agitation, irritability, sleep disturbance (since the symptom arises during sleep or wakefulness), and episodes of tachycardia. I call this sensation and accompanying symptoms *visceral vibratory vestibular disturbance* (VVVD). It is described further below.

Core symptoms are closely correlated with exposure, including being at home, the direction and strength of the wind, whether turbines are facing the home, and the presence of moving blade shadows. Core symptoms all resolve immediately or within hours away from the turbines, with the exception of disturbances of concentration and memory, which resolved immediately in some cases or improved over weeks to months in others.

Sleep disturbance. Thirty-two subjects (17 males age 2-64 and 15 females age 2-75) had disturbed sleep. Types of sleep disturbance included: difficulty getting to sleep, frequent or prolonged awakening by turbine noise, frequent or prolonged awakening by awakened children, night terrors (both 2½-year-olds, B3 and G5), nocturnal enuresis (one 5-year-old girl, G4), nocturia (six women age 42-75 and one man age 64; B2, C2, E2, F2, F4, H2, D1), excessive movement during sleep (one 8-year-old boy, H3), excessive nighttime fears (two 5-year-olds, a girl and a boy, C8 and G4), and abrupt arousals from sleep in states of fear and alarm (four women age 42-57; C2, F2, H2, I2). Other adults, though not fearful when they woke up, awoke with physical symptoms similar to their daytime symptoms of anxiety/agitation/internal quivering (three men age 42-64 and two women age 32-53; D1, F1, J1, B2, G2). Four people slept well, including the one infant (G6), a 19-year-old woman (B3), a 47-year-old woman (J2) and her 8-year-old son (J4). It was unclear whether a 56 year-old man with dementia, bipolar disorder, Parkinson's disease, and disturbed sleep at baseline (E1) slept worse than usual or not.

With three exceptions, all types of sleep disturbance resolved immediately whenever subjects slept away from their turbine-exposed homes, including the adult nocturia and the 5-year-old's nocturnal enuresis. A 49-year-old man with a preexisting sleep disturbance (J1) took two nights to get back to his baseline, and a 45-year-old man (C1) and a 42-year-old man (F1) did not improve all the way to baseline, thought to be due to coexisting depression after abandoning their homes.

Headache. Nineteen subjects experienced headaches that were increased in frequency, intensity, and/or duration compared to baseline for that person. Eight were male (age 6-55) and eleven female (age 12-57). Eight had pre-existing migraine (C2, C3, C4, C5, C6, F1, G1, G2). Two women (one a migraineur, one not; C2, E2) had severe headaches provoked by shadow flicker. All other exposure-related headaches were triggered by noise alone. Recovery from headaches generally took several hours after the exposure ended.

Headache risk factors were examined in a subset of the study group that included all subjects age 5 and older (N=34), since the younger children in the study (age <1 to 2) were not reliable sources of information on headache. The occurrence of unusually severe or frequent headaches during exposure was significantly associated with pre-existing migraine disorder ($\chi^2 = 8.26, p = 0.004$). All 8 subjects with pre-existing migraine experienced headaches that were unusually intense, frequent, or prolonged compared to their baseline headaches. Of the 26 subjects without pre-existing migraine, 11 also experienced unusual or severe headaches during exposure. Two of these were children of migraineurs not

known to have migraine themselves (a girl age 17 and a boy age 6; F3, G3). All children or teens (through age 21) who had headaches during exposure were migraineurs or children of migraineurs.

Once migraine was factored out as a risk factor, 9 of 17 subjects over age 22 without a history of migraine still had headaches of increased intensity, duration, or frequency during exposure to turbines. I found no significant correlation within this group between headache and the presence of serious underlying medical illness ($\chi^2 = 0.486$, $p = 0.486$), present or past mental health disorder ($\chi^2 = 0.476$, $p = 0.490$), tinnitus or hearing loss at baseline, motion sensitivity at baseline, or tinnitus, disequilibrium, or VVVD during exposure.

In summary, a little more than half (19) of the 34 study participants age 5 and older experienced unusually severe headaches during exposure. Migraine was a statistically significant risk factor but was present in less than half (8) of the 19 subjects with worsened headache. Children and teens up to age 21 with headaches either had known migraine or were the children of migraineurs. Nine of the 19 headache subjects were adults without clear risk factors, showing that while people with migraine are more likely to have headaches of unusual intensity, duration, or frequency around turbines, so can other adults without identified risk factors.

Tinnitus and ear sensations. Fourteen subjects (nine males age 19-64 and five females age 33-57) experienced tinnitus that was new or worse in severity or duration than at baseline. For two men (age 55 and 64; B1, D1), the tinnitus at times interfered with their ability to understand conversation. Four of the 14 subjects experienced particularly disturbing kinds of tinnitus or noise which was perceived to be inside the head (two men age 42-55 and two women age 52-57; B1, F1, H2, I2). This sensation was painful for two subjects. Tinnitus tended to resolve over several hours after exposure ended.

Tinnitus risk factors were examined in subjects age 16 and older, since the youngest person with tinnitus was in this age group. The subject with dementia (E1) was excluded, since there was no information on his hearing status or tinnitus. Sample size was 24 subjects. The occurrence of new or worsened tinnitus in the presence of turbines was significantly correlated with previous noise exposure ($\chi^2 = 6.17$, $p = 0.013$), tinnitus prior to exposure ($\chi^2 = 5.71$, $p = 0.017$), and baseline hearing loss ($\chi^2 = 4.20$, $p = 0.040$). Tinnitus during exposure did not show a significant relationship with pre-existing migraine or motion sensitivity, or with headache or VVVD during exposure. Tinnitus during exposure showed a weak correlation with dizziness/disequilibrium during exposure ($\chi^2 = 3.60$, $p = 0.058$)