Research on the impacts of wind turbine noise on humans: sound, perception, health (RIBEolH)

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ABSTRACT

Wind energy is expanding rapidly in France as elsewhere in the world, but the population is worried about the health impacts of wind turbine noise and some people are more annoyed than the sound field measurements would suggest. The annoyance is often described as resulting from infrasounds (IS) whereas the acoustic pressures of IS emitted by wind turbines would be below the perception thresholds. However, the possible inaudibility of IS does not exclude their action on the inner ear or the central nervous system (CNS). In this context, we propose a Research project on the Impacts of wind turbine noise on humans, in terms of sound simulation/synthesis and perception, and its effects on human Health ("RIBEolH"). The objectives of RIBEolH project are:

- To assess the health effects of audible noise, low-frequency sounds (LFS) particularly, and IS, emitted by wind turbines.

- To better understand the auditory mechanisms associated with the perception of IS and LFS emitted by wind turbines.

- To better understand the effects of IS on the inner ear or CNS.

To address these objectives, RIBEolH is based on two complementary parts: an epidemiological study and a psychoacoustic and physiological study.

CONTEXT AND OBJECTIVES

Context

Wind energy is expanding rapidly in France, as elsewhere in the world, and constitutes an important means of action for the implementation of public policies (law on the energy transition of 2015). This orientation results in particular from the willingness to diversify energy sources to reduce dependence on fossil fuels and to reduce greenhouse gas emissions. Precise rules govern the design and installation of wind turbines in order to limit the acoustic field they produce when they operate and to decrease annoyance for residents. Thus, in France, the regulatory framework applying to wind turbines evolved in 2011 with the introduction of minimum installation distances of 500 metres from any dwelling and the classification of wind farms as facilities classified for environmental protection (Decree No. 2011-984 of 23 August 2011 and three decrees of 26 August 2011). These texts provide in particular for noise measurements in the octave bands from 125 to 4 000 Hz. However, low frequency sounds (LFS, from 20 to 200 Hz, audible) and infrasound (IS, frequencies below 20 Hz, considered inaudible), which are more difficult to measure, are not taken into account.

Nevertheless, the people living near these installations is worried about the health impacts of noise emitted by wind turbines and some people are concerned about a significant annoyance that might be partly due to the nature of the noise emitted, which includes important low frequency components (audible or not), with a modulated temporal structure [1]. This annoyance is sometimes more severe than would be expected from estimates and measurements of the acoustic field or from existing knowledge of auditory sensitivity to LFS and IS. Indeed, to date, studies indicate that the sound pressures of IS emitted by wind turbines are below the hearing thresholds. However, while it was considered implicit that inaudible noise levels cannot have an impact on human health, some experimental studies on animals and humans suggest biological plausibility regarding the potential effects on the organism of exposure to IS and LFS [2].

The WHO Environmental Noise Guidelines for the European Region published in October 2018, point out that evidence for health effects from exposure to wind turbine noise is either not available or of poor quality [3]. Indeed, to date, few epidemiological studies have investigated the effects of audible noise from wind turbines and all, but one, show methodological limitations that make their results controversial [4]. However, none of these studies specifically addressed the health effects of IS or LFS emitted by wind turbines.

Thus, it is not yet possible to conclude on the impact of wind turbine noise on health. The WHO and the ANSES (the French Agency for Food, Environmental and Occupational Health & Safety) therefore recommend to carry out epidemiological studies on a large number of individuals, using objective measurements of the health status of participants, including the International Commission on Biological Effects of Noise (ICBEN) scale to assess annoyance, and measuring wind turbine noise exposure with an objective and standardized approach over a wide range of levels and frequencies (including LFS) [3-4].

Objectives and research hypotheses

The objectives of the RIBEolH project are:

• To evaluate the health effects (in the broad sense, including annoyance) of audible noise (in particular LFS) and IS emitted by wind turbines. It will also be necessary to better understand annoyance and whether there are any relationships between annoyance and some variables

such as environmental concerns or pro-environmental behaviour. The underlying research hypothesis is that not only audible noise - in particular LFS - but also IS, emitted by wind turbines in normal operation would lead to adverse health effects in people living near wind farms (effects on the cochleo-vestibular system, sleep disturbances, stress, cardiovascular diseases, psychological disorders and annoyance).

• To better understand the specific characteristics of audible noise - in particular LFS - and IS emitted by wind turbines, to better understand the auditory mechanisms associated with the perception of IS and LFS emitted by wind turbines (particularly the perception of sound intensity – loudness - and amplitude modulations), and their association with annoyance. The underlying research hypothesis is that IS and LFS could be perceived and could be annoying at the levels emitted by wind turbines. Currently, the auditory sensations induced by wind turbines are quantified using the A-weighted average sound level (dB(A)), but it is well known that it is not adapted to account for the perception of sound intensity at these frequencies.

• To better understand the effects of IS on the inner ear or central nervous system, which may explain some of the symptoms sometimes described by people exposed to IS and who complain about them. The underlying research hypothesis is that inaudible sound levels could have physiological effects on the human auditory system and these effects could be associated with annoyance.

In order to achieve these objectives, the RIBEolH project is based on a methodology structured in two complementary parts. The first phase is based on the implementation of an epidemiological study designed to better understand and quantify the health effects of noise emitted by wind turbines. The second phase is based on a psychoacoustic and physiological study, conducted under controlled conditions, to understand the auditory mechanisms associated with the annoyance due to IS and LFS emitted by wind turbines.

METHODS

Epidemiological study

The protocol of the epidemiological study will be based in particular on the results of the Cibelius feasibility study [5].

Identification of participating wind farms

The methodology proposed in Cibélius made it possible to determine classes of audible noise levels due to wind turbines, within which it was possible to count the exposed populations for all wind farms in metropolitan France in 2017: nearly 250,000 people during the day and 350,000 people at night were exposed to noise levels due to wind turbines varying between 30 and 60 dB(A). Nearly 63% of the exposed people were located in three regions of France (Hauts de France, Brittany and Normandy). These three regions also had the highest levels of exposure.

The wind farms to be included in the study will be partly selected in these three regions according to the number of people potentially exposed to a variety of noise levels due to wind turbines. This number was estimated in Cibelius.

Selection of participating local residents and data collection

This study will be conducted with approximately 1,200 residents of the selected wind farms. A face-to-face questionnaire administered by an interviewer will collect information on the

participant's demographic and socio-economic characteristics, housing characteristics, perception of the environment and external noise sources, lifestyle, health status (including sleep disturbances, hypertension, psychological disorders, stress and annoyance) and noise sensitivity in general. Already validated questions will be used such as the 12-item version of the General Health Questionnaire, the Pittsburgh Sleep Quality Index (PSQI) and the Perceived Stress Scale (PSS). This questionnaire was built and tested in Cibelius. In addition, objective measurements of certain health conditions will also be made (blood pressure, heart rate and stress levels through cortisol concentration).

Noise exposure assessment

Exposure to audible noise - including LFS - and IS, emitted by the wind turbines of all participants will be estimated using numerical simulations based on noise prediction engineering models that will make it possible to estimate wind turbine noise emission and propagation, and thus to estimate exposure on building's facade. The exposure will be assessed for different periods (day, evening, night), for different particular situations (maximum or average exposure, particular wind conditions). An estimate of exposure inside buildings will be made using flat-rate laws of acoustic insulation of facades. Acoustic measurements will be carried out on a sub-sample of about 100 residents, inside and outside the home, to validate or adjust the model or the fixed laws used.

Psychoacoustical and physiological study

The psychoacoustical and physiological study will consist in carrying out, in a laboratory, psychoacoustic and physiological measurements in a controlled environment using sounds recorded and synthesized with a physical model, accounting for different operating conditions of wind turbines and for representative propagation conditions. This approach allows the synthesis of sounds based on well-identified and controlled physical parameters, which will make it possible to precisely determine the parameters that have an important role in the effects of noise emitted by wind turbines on loudness and annoyance. Psychoacoustic work in the laboratory will focus on loudness and auditory sensations related to amplitude modulation in order to understand their relationship to annoyance. An annoyance indicator based on acoustic and non-acoustic variables (such as noise sensitivity) will be proposed. This indicator will be compared with annoyance measured during the epidemiological study. Finally, physiological measurements of cochleovestibular responses (otoacoustic emissions, electrocochleography, videonystagmography) will be performed on participants exposed to IS in order to test the hypothesis from the literature that non-audible IS may affect hearing and/or balance.

All the experiments will be conducted in a room specially designed for the restitution of IS. Indeed, one of the problems with the restitution of LFS and IS is that the sound levels involved at these frequencies are difficult to achieve. A room has therefore been specially built that make it possible to reach the levels of LFS and IS encountered in the environment and particularly concerning the sounds emitted by wind turbines, and to control the acoustic field at one particular position (the one of the participants during the experiments), ensuring a sound reproduction of very good quality.

PROJECT IMPACT

The RIBEolH project will improve knowledge on the effects of wind turbine noise on health and on whether or not LFS and IS should be included in the studies of acoustic impact on inhabitants located close to wind farms. It will also increase the understanding of how LFS and IS are felt.

Epidemiological results will complement the very few studies in this field. They will be used to determine if there are any health effects related to wind turbine noise. They will help inform future work on recommending noise thresholds for wind turbine development, for which there is currently a lack of knowledge [3].

Beyond wind turbine noise, the results on the perception of IS and LFS will allow progress in the knowledge of the perception or annoyance processes concerning these frequencies whatever the type of noise, and the physiological mechanisms in the inner ear at the origin of their perception.

A better understanding of the potential health risks of wind farms will make it possible to support the development of these renewable energies in a controlled manner and with respect for the exposed populations.

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REFERENCES

[1] Ioannidou C, Santurette S, Jeong CH. Effect of modulation depth, frequency, and intermittence on wind turbine noise annoyance. J. Acoust. Soc. Am. 139(3):1241-1251 (2016).

[2] Salt AN, Hullar TE. Responses of the ear to low frequency sounds, infrasound and wind turbines. Hearing Research 268(1-2):12-21 (2010).

[3] WHO, Environmental Noise Guidelines for the European Region. Copenhague, Denmark: World Health Organisation (2018).

[4] Anses. Évaluation des effets sanitaires des basses fréquences sonores et infrasons dus aux parcs éoliens : Saisine 2013-SA-0115 : avis de l'ANSES. Rapport d'expertise collective, Agence Nationale de Sécurité Sanitaire (Anses), 304 pages (2017).

[5] Écotière D, Demizieux P, Guillaume G, Champelovier P, Giorgis-Allemand L, Evrard AS. Quantification of noise exposure from wind turbines in France. Paper presented at the 13th ICBEN International Congress on Noise as a Public Health Problem, Stockholm, Sweden (2021).