Quantification of noise exposure from wind turbines in France

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ABSTRACT

The WHO guidelines on environmental noise highlight that evidence on the health effects of wind turbine noise is either non-existent or of poor quality. In this context, a feasibility study was conducted in France. The objective was to suggest a methodology for calculating wind turbine noise in order to quantify the number of windfarms' residents exposed to different levels of this noise. Based on a literature review, the Harmonoise model was selected for noise exposure calculation. The contribution of a wind farm varies from 35 dB(A) to 45 dB(A) for distances from 500m to 1500m, depending on weather conditions. Compared to other environmental noise sources (e.g. transportation), the noise exposure is very moderate and the total number of exposed people is very low: about 262,000 people during the day and 363,000 people at night, i.e. about 0.4% and 0.5% of the French population in 2017. Nearly 85% of the exposed population is exposed to levels below 40 dB(A). These results are the first ever assessment of noise exposure from wind turbines on the scale of the entire metropolitan French territory.

INTRODUCTION

Wind energy is expanding rapidly in France, as it is everywhere else in the world. Specific rules govern the design and implementation of wind farms in order to limit the noise they produce when in operation. However, the population living near these installations is often concerned about the health impacts of the noise emitted by wind turbines and there is a lack of available scientific data on this topic.

The WHO guidelines on environmental noise published in October 2018 point out that the evidence on the health effects of noise from wind turbines is either non-existent or of low quality [1]. The WHO, and Anses in France, therefore recommend implementing epidemiological studies [1-3]. However, a number of issues remain to be overcome before such a study can be carried out in France.

The first issue concerns the estimation of exposure to noise produced by wind turbines. Indeed, the quality of epidemiological studies evaluating the risks related to environmental exposures depends in part on the quality of the estimation or measurement of the participants' exposure. But, in the case of a large-scale epidemiological study, given their cost, noise measurements in a large number of residents would not be feasible and it would therefore be necessary to use noise prediction models. Currently, there is no real consensus on a wind turbine noise prediction model and it is necessary to provide validation criteria to identify the most relevant model.

The second issue concerns the counting of the number of people exposed to wind turbine noise. Unlike other sources of noise pollution (e.g., transportation noise), wind farms are usually built in sparsely populated areas, and consequently the number of people potentially exposed to the noise emitted by the wind turbines seems *a priori* much less important than the number of residents exposed to other sources of anthropic noise, such as transportation noise, for example. In order to be able to demonstrate, in a statistically rigorous way, an association between a health condition and the level of wind turbine noise, if such an association exists, it would be necessary to recruit a sufficient number of individuals exposed to different and relatively contrasting noise levels.

In this context, a feasibility study for an epidemiological study called Cibélius (Connaître l'Impact du Bruit des ÉoLIennes sUr Santé) was conducted in France between 2017 and 2019. The objective was to propose a methodology for calculating wind turbine noise and to identify the number of local residents exposed to different levels of wind turbine noise.

METHODS

Selection of a wind turbine noise prediction model

In order to estimate the exposure to wind turbine noise, it is necessary to choose a noise propagation model appropriate to wind turbine noise context. This model was selected from a literature review based on the following criteria that are essential in the context of wind turbine noise: ability to take into account a high sound source (height of at least 80m), topography properties, meteorological (wind speed and direction, temperature) and ground effects on sound propagation. The model must also be able to parameterize the sound power of the source as a function of the wind speed. While some research propagation models can meet these criteria for wind turbine noise [4-7], they are not suitable for modelling wind turbine noise on a scale as large as a country's territory due to their high computational time demands. Only engineering models can handle a large-scale territory, and among them the Harmonoise model [8] was preferred here to more commonly used acoustic engineering models such as ISO 9613-2 [9], because of its good ability to take into account meteorological conditions in a much precise more detailed way, and also the effect of the ground on sound propagation.

Estimation of noise exposure from wind turbines

The selected noise prediction model was used to produce a noise mapping of all wind farms at the scale of the whole metropolitan French territory. This mapping was built in three steps.

- *First step: constitution of a database with the required characteristics for the noise prediction of wind farms in metropolitan France*

The characteristics required for each wind turbine are its precise geographical position, its height and its sound power according to the wind speed. These data were obtained by crossing a 2017 database obtained from www.thewindpower.net, giving the location of the wind farms (Figure 1), the height and the electrical power of the wind turbines, and a topographic database

(BDTOPO® [10]) of the National Institute of Geographic and Forestry Information (IGN) giving the absolute position of each wind turbine within wind farms.

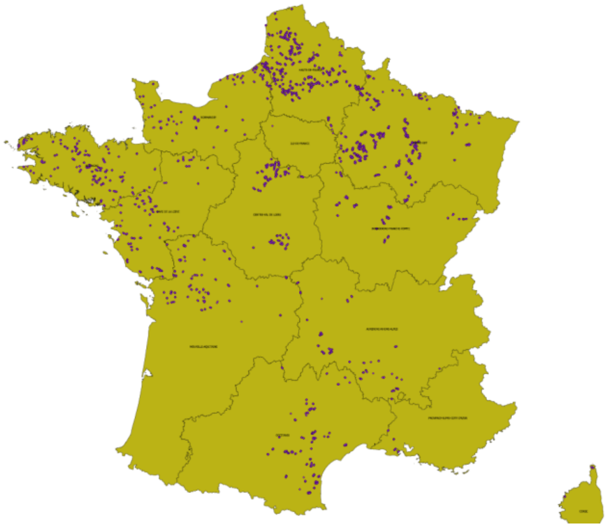

Figure 1: Localisation of metropolitan French wind farms (2017, www.thewindpower.net)

- *Second step: calculation of the noise contributions of the wind turbines near the dwellings of the wind farm residents*

Each wind turbine was modeled as a noise source point, located at the hub of the wind turbine, whose noise emission corresponds to a linear sound emission spectrum (-4 dB/octave [11-13]). The global sound power level of each wind turbine was estimated from its electrical power, and considering a wind speed of 7m/s at 10m height (nominal operation of the wind turbines in steady state). Sound attenuation due to sound propagation between each wind turbine and each dwelling was evaluated using the Harmonoise method [8]. Sound levels were evaluated for two typical meteorological conditions, corresponding to daytime and night-time periods, for eight wind directions (from 0° to 315°, in 45° steps), and for standard environmental conditions (temperature 10°C, humidity 70%, partially sound absorbing soil). In the Harmonoise model, these two conditions correspond respectively to the meteorological stability class S3 and S5 [8]. The topographic data used in the propagation model came the BDTOPO® database [10]. The calculations provide isophones around all the wind farms and give access to the exposure of each local resident dwelling. An example of such a result is shown in Figure 2.

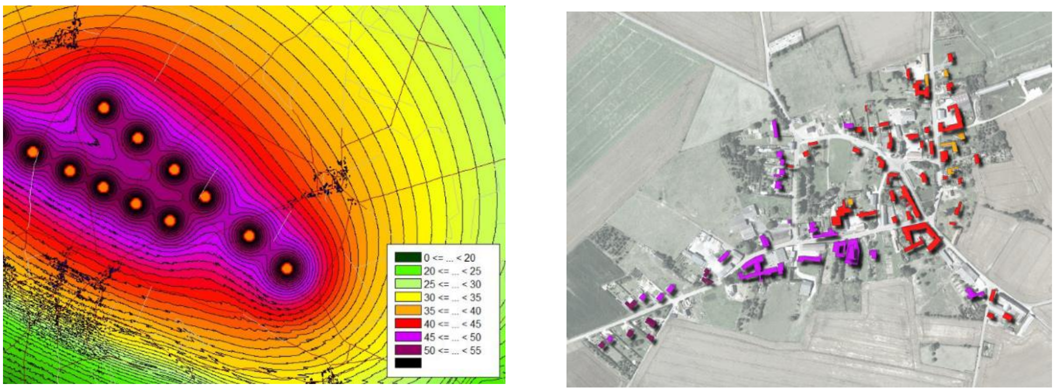

Figure 2: Example of the result of the calculation of the radiated noise from a wind farm (left), and of the exposure of the buildings in a nearby village (right).

- *Third step: determination of sound exposure gradients*

Finally, for each of the parameter configurations, seven classes of exposure levels to wind turbine noise at the level of the building facades of residents of all the wind farms in metropolitan France surveyed in 2017 could be defined: [30; 35[, [35; 40[, ..., [55; 60[, >60 dB(A). Exposures below 30 dB(A) are too low to be considered as significant and were therefore not retained.

Counting the number of people exposed to wind turbine noise

The classes of noise exposure levels produced by wind turbines were cross-referenced using the QGIS [14] GIS tool with the populations provided by the national land occupation files database (MAJIC) updated in 2016 [15]. This database was used in the framework of the creation of the French strategic noise maps of major infrastructures [16]. The number of people exposed to noise produced by wind turbines during the day and night was thus determined at the scale of metropolitan France, as well as of the 13 administrative metropolitan French regions.

RESULTS AND DISCUSSION

Estimating the wind turbine noise exposure

Noise levels observed for the contribution of a wind farm typically vary from 35 dB(A) to 45 dB(A) for distances of 500m to 1500m. For a given distance, the sound levels may also show some variability due to changing weather conditions, which here consists only of a change in wind direction. As wind speed is considered as constant (7 m/s at 10m high), and other variabilities could not be taken into account (temperature, ground impedance), the variability of the sound levels observed in the computational results is less important than what can be observed *in situ* [17] or by estimation in the literature [18-19].

It should be noted that the choice of a constant wind speed corresponding to the nominal operation of the wind turbines leads to an overestimation of the real exposure to wind turbine noise, as it considers that wind turbines are constantly in operation throughout the day, which is different from reality. This overestimation is not a problem here as the initial purpose of the study is to obtain the upper limit of wind noise exposure in France.

Counting the number of people exposed to wind turbine noise

The total number of people exposed in metropolitan France to wind farm noise higher than 30 dB(A) is approximately 262,000 people during the day and 363,000 people at night, which corresponds to approximately 0.4% and 0.5% of the 2017 French population (Figure 3). For comparison, for transportation night-time exposure in France in 2017, the population exposed to noise is 10,400,000 people for road noise, 5,000,000 for railway noise and 460,000 for aircraft noise, i.e. 15%, 7% and 0.7% of the French population in 2017, respectively [20]. It should be noted that the latter figures are underestimated, compared to reality, because they only take into account major transportation infrastructures, and cities with more than 100,000 inhabitants (see [21] for more details).

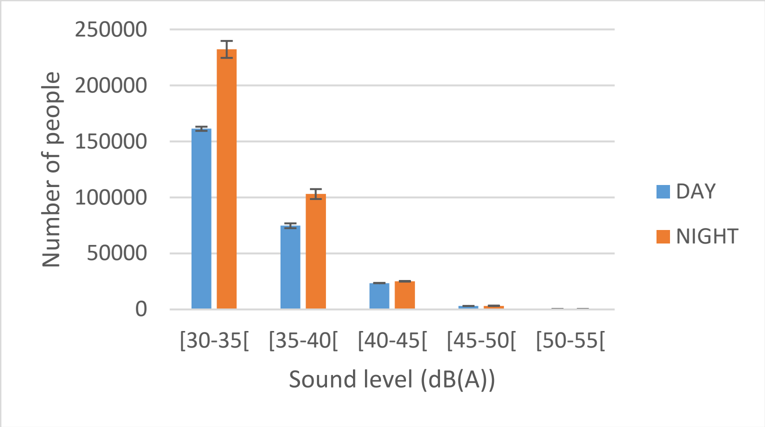

Figure 3: Number of people exposed to wind turbine noise, for day and night. Error bars: +/- 1 standard deviation

The majority of the mean sound level due to wind farm noise is below a sound level of 35 dB(A), and more than 90% of the population exposed to wind turbine noise is exposed to levels below 40 dB(A), for both day and night (Figure 3). The variations in sound levels generated by the influence of wind direction at each site do not lead to significant uncertainty in these results: the standard deviations found are less than 2% of the mean value regardless of the level of sound exposure (Figure 4).

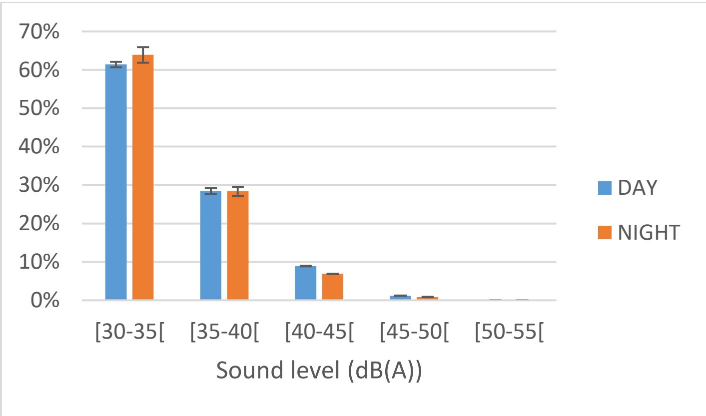

Figure 4: Distribution of people among the exposed population. Error bars: +/- 1 standard deviation

Analysis by region shows that most of the exposed population is located in the Hauts de France (40%) (Figure 5). Bretagne, Grand-Est and Normandie each account for 12% of the exposed population. These three regions also have the highest exposure levels.

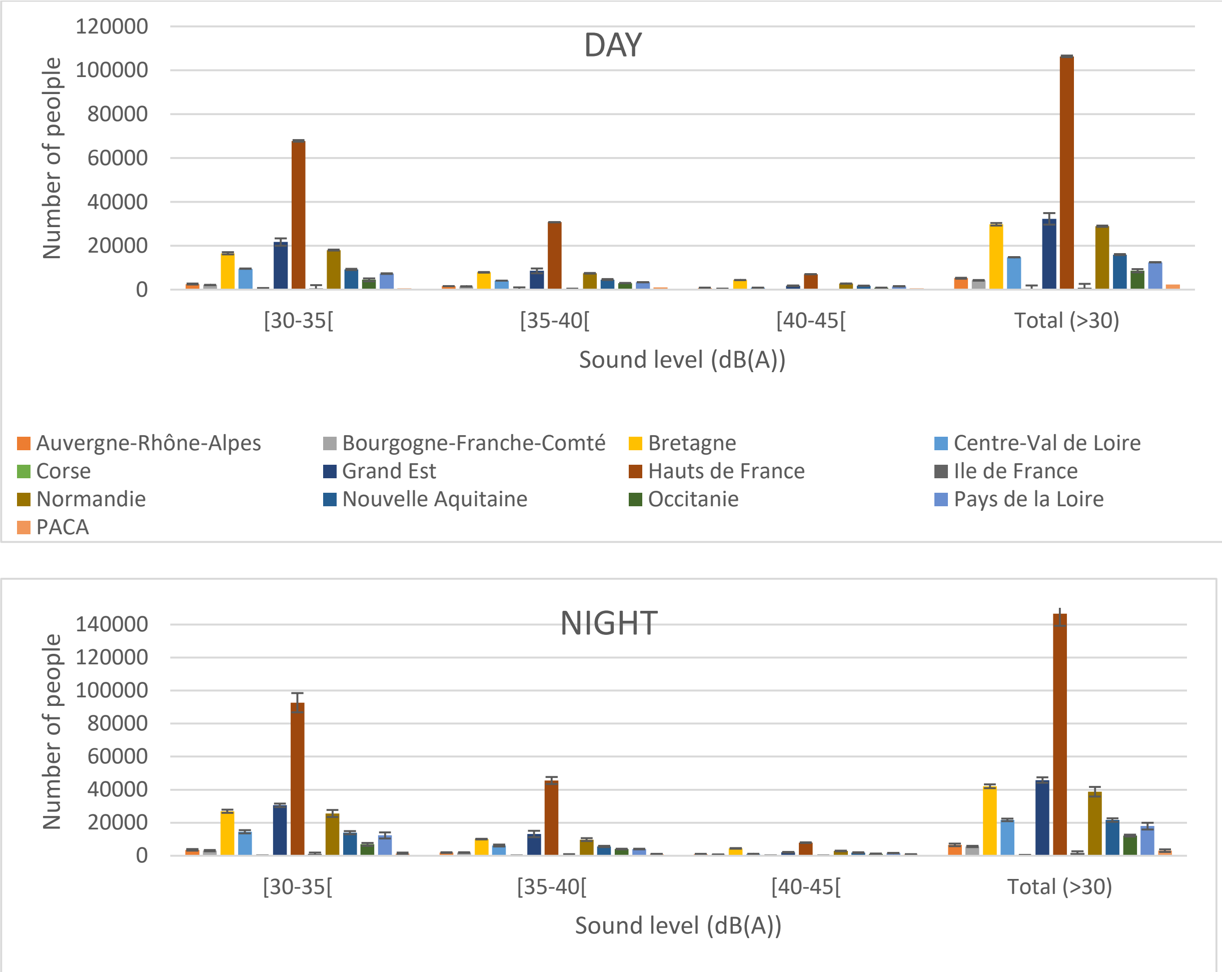

Figure 5 : Distribution of people among the exposed population, by region. Error bars: +/- 1 standard deviation.

The distribution of noise levels of exposed populations is also relatively similar from one region to another, for both day and night, with a maximum between 30 dB(A) and 35 dB(A) (Figure 6). Only the Corsica and Provence-Alpes-Côte d'Azur (PACA) regions have a higher maximum exposure level for exposed residents between 35 dB(A) and 40 dB(A). However, this finding is marginal and not very significant in the case of Corsica, given the small population exposed (Figure 6).

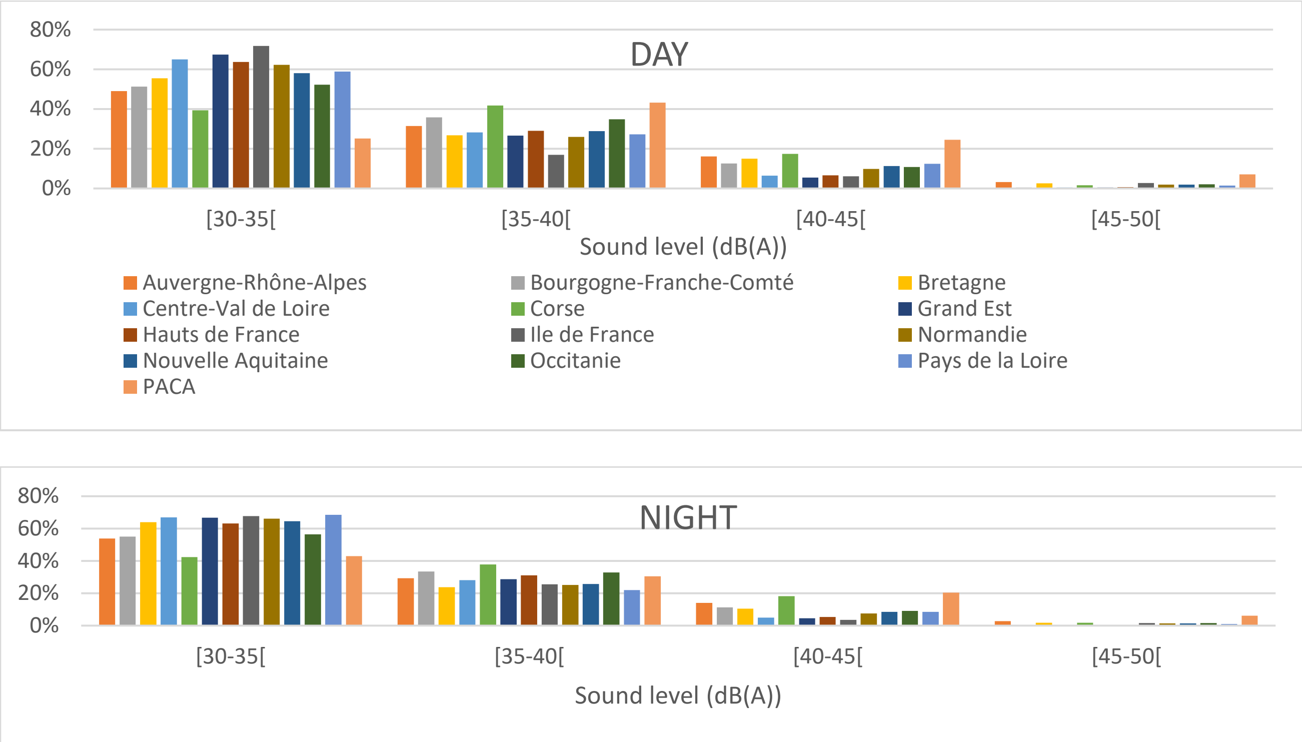

Figure 6 : Distribution of noise exposure within noise classes, by region.

CONCLUSION

The objective of the Cibelius feasibility study was to propose a methodology for calculating wind turbine noise and to identify the number of residents exposed to different levels of this noise. These two identified issues have been addressed. A methodology was designed which allows to evaluate the wind turbine noise levels for all the wind farms in France. Exposure classes could be defined and the number of people in each class could be estimated.

Overall, it should be noted that the sound levels recorded for the contribution of the wind farms vary from 35 dB(A) to 45 dB(A) for distances of 500m to 1500m, depending on meteorological conditions. They are quite moderate compared to other noise sources (e.g. transportation). The total number of people exposed to wind turbine noise is approximately 262,000 during the day and 363,000 at night, or about 0.4% and 0.5% of the French population in 2017. Nearly 85% of the population exposed to wind turbine noise is exposed to levels below 40 dB(A), day and night. It is important to note that, due to some assumptions in this study (wind speed at nominal operation, wind turbines constantly in operation throughout the day), the noise exposure, and therefore the number of people exposed to wind turbine noise, is probably overestimated.

The results of this Cibelius feasibility study are the first assessment of exposure to wind turbine noise in metropolitan France. They show that an epidemiological study to examine the health effects of noise from wind turbines is feasible on this geographical scale. The work carried out has led to the proposal of a methodology for conducting such a study, which is currently ongoing on the Ribeolh project [22].

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Conflicts of interest

The authors declare that they have no interests related to the content of the article.

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