Journal of Environmental Protection, 2017, 8, 1178-1193
http://www.scirp.org/journal/jep
ISSN Online: 2152-2219
ISSN Print: 2152-2197

Acoustic Impact Studies (AIS) of Wind Farms in Uruguay: A Methodology Proposal

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How to cite this paper: González, A.E., Rezzano Tizze, N., Gianoli Kovar, P., Paz Urban, M. and Lisboa, M.R. (2017) Acoustic Impact Studies (AIS) of Wind Farms in Uruguay: A Methodology Proposal. *Journal of Environmental Protection*, **8**, 1178-1193.
https://doi.org/10.4236/jep.2017.810074

Received: August 17, 2017
Accepted: September 23, 2017
Published: September 26, 2017

Abstract

The fast growing development of wind power in Uruguay has encouraged research on many issues regarding environmental acoustics, especially those related to wind turbines operation. As every new power generation device of 10 MW or larger has to have an environmental license approval before building it, a methodology for Acoustic Impact Studies (AIS) was needed. This paper presents a methodology proposal to carry out AIS, taking into account the peculiarities of the Uruguayan status. Determining the area where the studies should be done, demands for the base line of sound pressure levels, predicting sound pressure levels during the operation of future wind farm and main lines for the environmental management plan are included in this proposal. Uruguayan current national guidelines to noise pollution levels are also presented.

Keywords

Acoustic Impact Study, Acoustic Impact Assessment, Wind Farms, Wind Turbine, Environmental Impact Assessment

1. Introduction

Uruguay is a small country in South America. Its surface is less than 177.000 km^2 and it has about 3:500.000 inhabitants. As the country has no petroleum, the Energetic Politics 2005-2030 for Uruguay has prioritized the diversifying of the energy matrix and thus, exploitation of alternative and renewable energy sources rose to a major scale [1].

Renewable sources have been strongly promoted. As Uruguay is a very windy country, wind energy has received particular attention, offering an authentic green energy as a reliable alternative to traditional sources. Currently, Uruguay has more than 1200 MW of installed power relying on wind [2].

According to the national Energy Balance 2016 [2], Uruguay has an installed electricity generation capacity of 3912 MW, most of which relies on renewable sources: 39% of it (1538 MW) refers to hydropower generation and 31% (1212 MW) to wind generation. The energy gross generation in 2015 was about 11,500 GWh and more than 90% of it was on renewable sources. Energy consumption is rising as well; it was about 3.2 MW/inhab/year in the same year.

Although the demands on Land Planning [3] and Environmental Impact Assessment [4] are clear, there is still a lack of national rules about available sound pressure levels; currently, only a set of guidelines on noise pollution is active [5].

This paper presents a methodology proposal for the Acoustic Impact Studies (AIS) of new wind farms in Uruguay. Taking into account international and national experiences and references, a proposed simplified predictive model about environmental sound pressure levels due to the operation of large wind turbines has been developed [6] [7].

2. Why a New Methodology Proposal

2.1. The Right Moment

When the encouragement to wind energy was consolidated in Uruguay, the studies of Van den Berg had been published a few years ago [8]. He demonstrated that the application of the preferred tool for predicting environmental sound pressure levels due to stationary noise sources (the method of ISO Standard 9613-2 [9]) to the case of large wind turbines noise could conduct to great underestimations, especially under certain atmospheric conditions.

Since prevention is the most effective management way to avoid and/or minimize possible post-construction environmental problems, the Uruguayan Energy and Environment Authorities decided to get a national methodology for predicting sound pressure levels due to large wind turbines in rural areas [6].

2.2. The National Regulatory Framework

Uruguay has an environmental regulatory framework with heterogeneous level of consolidation. Some areas are well covered (e.g. water quality or environmental impact assessment) while others still need a lot of work (e.g. air quality or noise pollution).

The Land Planning Act (2008) and its Decree 221/2009 [3] turned the management of land planning issues to the municipalities' duty. Changes on land use should be object of an environmental strategic assessment taking into account their environmental deleterious effects. However, most of municipalities are technically weak and some environmental emerging problems could be difficult for them to properly handle. Such is the case of noise.

The Environmental Impact Assessment Act and its Decree 349/2005 [4] enforces every power generation device with installed capacity greater than or equal to 10 MW to obtain its environmental license before the beginning of its construction. The first step to get this license is the communication of the project to the Environmental Authority, asking for an environmental classification.

The Environmental Authority classifies the projects according to their complexity and their expected effects on the environment. The possible classes are "A" (the lightest one), "B" or "C" (the most restrictive one). As most of the wind energy projects usually receive a "B" classification, they should be submitted to an Environmental Impact Study (EIS). The EIS should follow the usual methodologies; it should include an Acoustic Impact Study (AIS). Even if different prediction methods are used all around the world to do this kind of studies, the widest used one is [9].

2.3. Some Encouraging Features

Uruguay is a flatty, windy country. When working in flat areas, the prediction of sound pressure levels is simpler than in complex topography, as there are less significant propagation phenomena.

When we began working on this issue, some wind farms were just operating. Then, measuring sound pressure levels in different conditions (e.g. wind speeds, power generation, etc.) and at different distances from the wind turbines was possible.

Another interesting feature is that recording at least two years of wind climate before proposing a site for building a new wind farm is needed to support the site selection. So, our proposal lays on the hypothesis that characterizing the environmental baseline takes also a significant amount of time.

The previous experience of the research team was also a good starting point. Research Team on Renewable Energies at the Faculty of Engineering of Universidad de la República began working on wind energy on 1990. Besides, a great experience on noise pollution had been developed at the Department of Environmental Engineering of the same Faculty, with focus on environmental acoustics. The Research Team on Noise Pollution had cooperated with the development of acoustic maps building techniques and the National Guidelines for Noise Pollution [5]. As environmental management and assessment are also the Department's concerns, thus the Research Team on Noise Pollution was faced to a great challenge: helping to develop a better methodology about noise prediction from wind farms, to avoid and/or minimize possible post-construction environmental problems and cooperating with the process of sustainable development of the country. The close support of the Wind Energy Research Team was very important for succeeding.

3. Suggested Minimum Contents for Acoustic Impact Studies of Wind Farms

3.1. General Structure

Acoustic Impact Studies (AIS) of wind farms should include at least the following contents:

1) Establishing the area for baseline studies (first approach to the Expected Direct Influence Area, EDIA).

2) Identification of noise sources with incidence in the EDIA.

3) Enforced national and municipal standards about noise pollution in the EDIA.

4) Baseline regarding existing sound pressure levels in the EDIA.

5) Prediction of sound pressure levels during the operation of the wind farm.

6) Assessment of the expected acoustic impact.

7) Management assurance not to worsen the environmental acoustic quality.

8) Proposal of sound pressure levels monitoring during the operational phase.

3.2. Establishing the Area for Baseline Studies

The main strength of a good baseline is to give enough guarantees both to the future emitter and to the receivers about affecting or not of the environmental acoustic quality. Only airborne sound propagation will be considered for determining the EDIA.

1) A peripheral line 2,000 m (2 km) out of the layout of the wind farm should be defined.

2) If the owner of one allotment included in the EDIA signs a notarized commitment to authorize the installation of at least one wind turbine in it, any land owned by him shall be deemed as excluded from the EDIA, *i.e.*, excluded from the inside of the peripheral line defined in (1). The commitment must be binding with the allotment in case of selling, leasing or any other legal action by which the owner fails to define the possible uses of this land.

3) The EDIA should then be configured by that one defined in (1) taking from it the areas referred to in (2). It will be presented in a 1:10,000 or more detailed scale chart.

3.3. Identifying Existing Noise Sources Possibly Influencing on the Expected Direct Influence Area

At least the following elements should be marked in the abovementioned chart:

1) Boundaries of all the allotments and municipal registry numbers of each one.

2) Existing buildings and their current use (permanent, occasional or vacation housing, abandoned dwelling, school, police station, shop, industry, store, etc.).

3) Current land uses.

4) Current land coverage.

5) National and departmental routes, secondary roads and any other road in the study area or within 100 m of its boundaries, and the type of surface of each one.

6) Stationary noise sources (industries, leisure places, etc.) within the study area or outside which are thought to contribute to its noise immission levels.

7) Area noise sources (parking or loading docks, etc.) within the study area or outside which are thought to contribute to its noise immission levels.

3.4. Relevant Municipal Regulations regarding Sound Pressure Levels

The current municipal regulations, land planning and territorial ordering instruments concerning the EDIA should be identified through their number and date of enactment. A synthesis of their main regards concerning the current AIS should be attached.

At least for those with less than two years of enactment, the full text or the official URL from which they can be downloaded should also be provided.

3.5. Base Line of Sound Pressure Levels

The minimum requirements for the baseline for sound pressure levels in the EDIA are listed below.

3.5.1. Existing Noise Sources

The following up-to-date information regarding the existing noise sources identified in 3.3 shall be provided:

1) For every route or road within the study area: classified traffic flow and its seasons.

2) For every stationery and area noise sources located at less than 500 m from a not-abandoned existing building, its description and purpose should be indicated, if it is state-owned or private-owned, operating hours and some relevant quantitative indicators to measure the business.

3.5.2. Selection of Sound Pressure level Measurement Points

The minimum number of points where the immission sound pressure levels are to be measured are:

1) Every not abandoned housing and accommodation, every schools or educational centers in the EDIA.

2) Other not abandoned buildings with any other use, which are located less than 500 m far from an identified existing noise source (stationary or area source) or from any national or departmental route.

Other control points where measuring sound pressure levels could be useful are the boundaries between side-by-side allotments where wind turbines are not to be installed, as well as the borderline of the study area.

In any case, the microphone of the sound level meter will be located at about 50 m (neither less than 20 m nor more than 100 m) from the building, in the direction in which the distance to the wind farm is the shortest. Caution against screening, presence of animals, trees or other possible interferences should be taken.

3.5.3. Measuring Instruments

At least Class 2 instruments (according to IEC 61672-1:2013 Standard) should be used. The equipment shall be capable of storing at least one week of data, with a sampling time of not less than 1 minute nor more than 10 minutes in duration.

Measurements shall be made with fast response and in standard octave bands at least between 16 Hz and 16,000 Hz, or in standard third octave bands covering at least from 12.5 Hz to 20,000 Hz. Lower frequencies recordings are welcome.

Although spectral analysis of environmental noise measurements is not usually required, as annoyance caused by wind turbine noise is usually related to certain frequency ranges, measuring the background noise spectral composition is strongly recommended as a good practice.

An omnidirectional microphone will be used. It shall be located at a net height (free of any obstacle) to be reported, between 3 m and 5 m. An anemometer shall be installed at a similar height and with similar considerations (to be reported) and between 30 m to 50 m from the sound level meter microphone. Wind data shall be recorded with the same (or similar) time step as that of the sound level meter. The location of both equipment will be presented in charts at scale 1:500 or more detailed.

At least at each one of the points selected in accordance with 3.5.2, one sound pressure levels measurement must be carried out. Measures should last at least one full week; if not possible, a continuous record of not less than 24 hours should be performed.

3.5.4. Information to Be Submitted

The minimum information to be submitted is listed below.

Sound pressure levels to be reported at each measuring point:

- For each measured hour, the following values will be presented:
  - A-weighted equivalent sound pressure level $L_{AF,eq}$;
  - A-weighted sound pressure level exceeded during 10% of the measuring time $L_{AF,10}$;
  - A-weighted sound pressure level exceeded during 90% of the measuring time $L_{AF,90}$;
  - A-weighted sound pressure level exceeded during 95% of the measuring time $L_{AF,95}$;
  - C-weighted equivalent sound pressure level $L_{CF,eq}$;
  - Arithmetic difference L_{CFeq}-L_{AFeq},
  - Average wind speed and direction.
- For each period from 20:00 to 8:00, the 60 minutes whose L_{AFeq} value is the smallest will be identified. For this data set, the calculated values of L_{AFeq}, $L_{AF,10}$, $L_{AF,90}$, $L_{AF,95}$ and the Z-weighted equivalent sound pressure level $L_{ZF,eq}$ for each one of the octaves- or third-octaves-bands should be reported.
- A magnetic version of the raw data stored by the equipment (sound pressure levels, wind speed and direction) must be submitted to the Environmental Authority without processing them in any way (presented in easily manageable files such as e-sheet or text document).

Graphs to be presented at each measurement point:

- Time evolving of $L_{AF,eq}$ during the whole measurement, discretized in intervals of time no longer than 30 minutes. It can be divided into no more than 3 graphs for easy understanding.

- Time evolving of $L_{AF,eq}$ for periods of 24 hours for all measurement days, discretized in intervals of no more than 30 minutes. Values of $L_{AF,eq}$, $L_{AF,10}$, $L_{AF,90}$ and $L_{AF,95}$ for each of the plotted 24 hour periods.
- Time evolving of $L_{AF,eq}$ for periods from 20:00 to 8:00 and from 8:00 to 20:00 for all measurement days, with the same time step as recorded raw data (maximum 10 minutes). Values of $L_{AF,eq}$, $L_{AF,10}$, $L_{AF,90}$ and $L_{AF,95}$ for each of the plotted 12 hour periods. Time evolving of the wind speed will be included in a secondary axis in every graph.
- Curves of permanence of A-weighted sound pressure levels for the period from 20:00 to 8:00 and from 8:00 to 20:00 for all measurement days, built with every surveyed data.
- For the 60 minutes with the lowest value of $L_{AF,eq}$ in each period from 20:00 to 8:00, the curves of permanence of the sound pressure levels in standard octave or third-octave bands upper to 250 Hz (according to available data).

Acoustic maps of the study area:

Considering the data of the whole measurement period, acoustic maps for times from 8:00 to 20:00 and from 20:00 to 8:00 will be built for $L_{AF,eq}$; $L_{AF,90}$ and $L_{AF,95}$. If the study area is 500 m far or less of an urban or suburban area, the maps must be done separately for business days and for weekends (and holidays, if applicable). Each map will provide the maximum and minimum values of measured $L_{AF,eq}$ at each point, the $L_{AF,eq}$ value calculated from all the measured data and the ($L_{CF,eq}$-$L_{AF,eq}$) extreme values.

3.6. Prediction of Environmental Sound Pressure Levels during the Wind Farm Operation

The prediction proposal included in this methodology is a simplified model developed at the Universidad de la República ([6] [7] [10] [12] [13]) aiming to provide an alternative to the calculation method of the ISO Standard 9613-2 [9]. As we found, it could lead to great underestimation of sound pressure levels at the receivers (over than 6 dBA) [6] [7].

3.6.1. Scope

Sound pressure levels shall be modeled in the whole study area, *i.e.* into a peripheral line 2,000 m out of the wind farm layout.

3.6.2. General

Predictions will be made by frequency bands and not by broadband (A-weighted) sound pressure levels.

Sound pressure levels will be reported in whole numbers.

Interpolating, extrapolating and/or drawing curves of equal sound pressure levels should only be done when the professional responsible for the AIS considers that the values obtained by any of these three actions are quite similar to those expected in the related points.

3.6.3. Required Data for Starting

Information for starting the AIS includes:

- Coordinates and height of noise sources and receivers
- Wind rose of speeds and directions during the year
- Permanence of different atmospheric stability conditions during the year
- Average and extreme relative temperatures and humidity in the study area
- Acoustic power of wind turbines as a function of wind speed in broadband A-weighted levels and in standard frequency bands.

Wind speed and temperature measured at different heights on the same vertical axis and night cloudiness are also important for AIS, even though they are not currently considered so.

3.6.4. Simplified Calculation Method

We have developed two methods: a detailed version and a simplified one. They differ on the way of obtaining the acoustic power spectrum of the wind turbines. Our most accurate method takes into account some fluid phenomena as wind turbulence or eddies releases. It allows working with low and very low frequencies below the audible range. Our simplified calculation method aims to use an empirical adjustment for reaching the sound pressure levels spectrum at 100 m from the tower of the wind turbine. Both methods then go through propagation issues in the same manner.

Here we will present our simplified calculation method for AIS of wind farms in the audible frequencies range. The flowchart in Figure 1 shows the main calculation steps; then, we will go deeper into each of them.

Wind speed at 10 m height

Even the acoustic power level of wind turbines directly depends on the wind

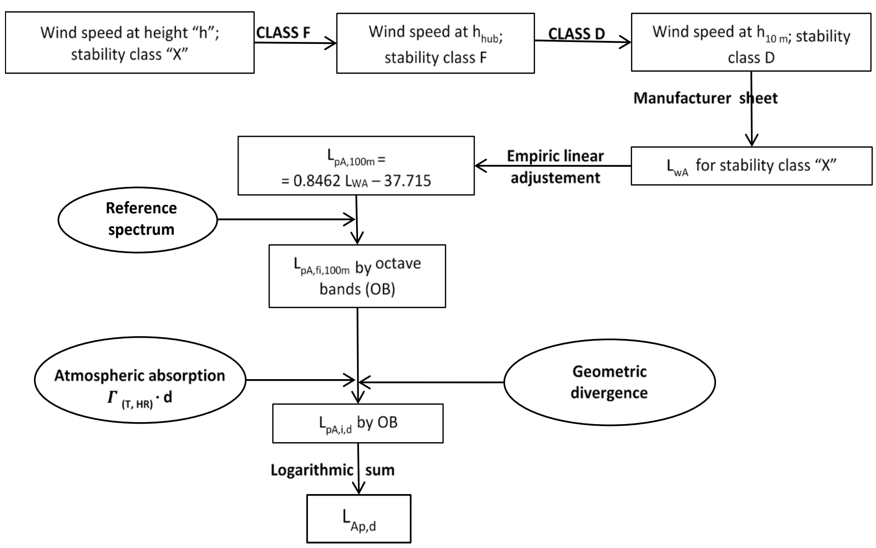

Figure 1. Proposed calculation method for immission sound pressure levels due to the operation of large wind turbines (adapted from [6] [10] [12]).

speed at the hub height, wind speed is usually measured at 10 m in height.

One of the main causes of underestimating immission sound pressure levels is related to computing the wind speed at h_{hub} using a neutral atmospheric profile with basis on its value at 10 m. This underestimation can be easily avoided/improved as it follows.

A simple—but enough accurate approach for an AIS—is to adjust the wind speed with basis on a vertical distribution fitted with a potential expression, as presented in Equation (1).

$$v_{hub} = v_{ref}\left(\frac{h_{hub}}{h_{ref}}\right)^{m} \quad (1)$$

Being:

v_{hub} = Wind speed at hub height h_{hub}

v_{ref} = Measured wind speed at a reference height h_{ref}

m = Coefficient depending on Pasquill class of atmospheric stability (see Table 1)

Since several authors refer that the usual values of m may lead to underestimation of the acoustic power, using the experimental values proposed by Van den Berg [8] is recommended to remain on the safe side.

The calculation procedure that we recommend to meet the wind speed at h_{hub} height taking into account its value at any other height h_{ref}, is as follows:

1) If the stability class to which v_{ref} corresponds is known, Equation (2) should be used:

$$v_{hub} = v_{ref}\left(\frac{h_{hub}}{h_{ref}}\right)^{m_{ref}} \quad (2)$$

2) If the stability class to which v_{ref} corresponds is not known, a stable atmospheric profile should be assumed, as shown in Equation (3):

$$v_{hub} = v_{ref}\left(\frac{h_{hub}}{h_{ref}}\right)^{0.65} \quad (3)$$

Once the wind speed at the hub height (v_{hub}) has been obtained from Equation (2) or Equation (3), a 'corrected' wind speed at 10 m in height should be calculated. This is the speed to obtain the acoustic power of the wind turbine. In this case, a neutral atmospheric condition should be assumed (class D, m = 0.40) and Equation (4) should be used:

Table 1. Values of m by Pasquill stability class.

Pasquill stability class		m	
Class	Description	Common bibliography values	Van den Berg experimental values
A	Highly unstable	0.09	0.15
D	Neutral	0.28	0.40
F	Highly stable	0.41	0.65

$$v_{10\text{ m}}^{\text{corrected}} = v_{hub}\left(\frac{10}{h_{hub}}\right)^{0.40} \quad (4)$$

This is the 10 m wind speed to be used for meeting the acoustic power level of the wind turbine from tables or charts provided by the manufacturer. Figure 2 illustrates the procedure.

Please note:

1) If the wind speed at the hub height is known, the wind speed at 10 m must always be obtained assuming a neutral atmosphere (even when the stability class is known not to be neutral).

2) For obtaining the sound pressure level resulting from a wind speed value measured at a height "*H*" (other from h_{hub}) in any given atmospheric condition "X": v_{hub} should be computed assuming the class of stability "X"; then, the 'corrected' wind speed at 10 m in height should also be computed by assuming neutral atmosphere (class D). The acoustic power shall be read from the datasheet provided by the manufacturer; it will also be associated with that atmospheric stability class: L_W^X .

Acoustic power level

Wind turbine manufacturers often provide tables or graphs relating the wind speed at 10 m in height (v_{10}) to the acoustic power level (in dBA) emitted by the machine in neutral atmosphere conditions. However, providing emission spectra in frequency bands is not so frequent. If this information is not available, a reference spectrum should be used (see reference spectrum Table 2, below).

Table 2 presents the values to be added arithmetically to the acoustic power level of the wind turbine (L_{WA}) to obtain the acoustic power levels in each octave band, also in dBA ($L_{W,f,A}$) (based on Jørgen *et al.* [14]).

Sound pressure levels at a distance of 100 m from the wind turbine

The immission A-weighted sound pressure level due to a wind turbine in its close environment depends on several factors. Aiming to introduce as few empirical adjustments as possible, in this simplified method the sound pressure levels at 100 m distance are intended to have the same spectral composition within

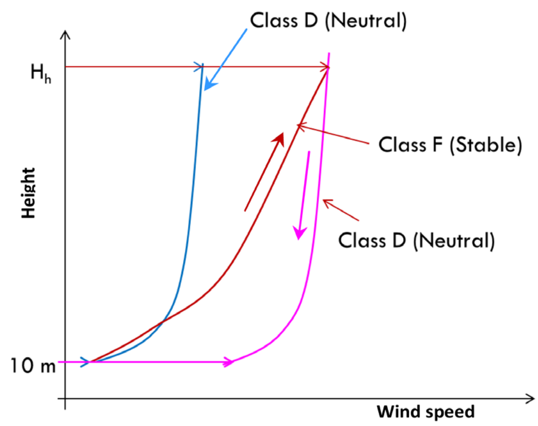

Figure 2. How to reach the wind speed at 10 m height to obtain $L_{W,A}$ (redrawn from [6] [13]).

Table 2. Reference spectrum of acoustic power of 2 MW wind turbines in octave bands (based on [14]).

f (Hz)	16	31,5	63	125	250	500	1000	2000	4000	8000
Add to L_{WA} (dB)	−44	−26	−21	−14	−7	−6	−6	−9	−12	−22

audible range as the acoustic power of the turbine. In other words, it is assumed that every possible phenomenon during sound propagation (e.g. atmospheric absorption) is negligible within the closest 100 m from the emitter.

For 2 MW wind turbines, the sound pressure level 100 m from a wind turbine $L_{pA,100\text{m}}$ shall be easily obtained by applying the linear adjustment shown in Equation (5) [10] (a previous adjustment proposal from our team [12] has been improved with more field data):

$$L_{pA,100\text{ m}} = 0.8462 L_{wA} - 37.715 \tag{5}$$

Once $L_{pA,100\text{m}}$ is retrieved, the A-weighted sound pressure level will be turned to its composition in octave bands by applying the manufacturer datasheet, a given or a reference spectrum (as that of Table 2). Assuming the acoustic power and the $L_{pA,100\text{m}}$ spectra have the same shape, values of $L_{pAf,100\text{m}}$ will be obtained by arithmetically adding the corrections presented in Table 2.

Sound pressure levels at a distance *d* from the wind turbine

To obtain sound pressure levels at a distance d greater than 100 m, only two processes should be considered in this simplified approach: atmospheric absorption and geometric divergence. Each octave band sound pressure level will then be propagated to a distance d and it will be corrected by the atmospheric absorption term.

Atmospheric absorption:

This physical phenomenon is only effective over long distances and at high frequencies. The depletion due to the atmospheric absorption within a distance d (greater than 100 m) should be obtained as shown in Equation (6) [15]:

$$\text{Abs} = \Gamma_i\left(\text{dB/km}\right) * d\left(\text{m}\right)/1000$$

Γ_i is the atmospheric absorption in the i-th frequency band in dB/km.

Coefficients Γ_i should be obtained by applying the calculation method of ISO Standard 9613-Part 1 [15] for the local values of temperature (T) and humidity (HR). In order to select the values of (T, HR) to be used, local statistics should be consulted. Otherwise, the calculations for Uruguay could be performed by default for temperatures of 20°C and 25°C with relative humidity of 70%. The values of the absorption coefficients Γ_i in these two conditions are presented in Table 3. They are given in standard octave bands centered between 63 Hz and 8000 Hz and expressed in dB/km; for lower frequencies, Γ_i = 0 will be assumed. As stated in ISO Standard 9613-Part 2, the absorption should be not greater than 15 dB in each octave band [9].

Geometric divergence:

Geometric divergence refers to the attenuation of a sound wave along its path

Table 3. Atmospheric absorption coefficients Γ_i in normalized octave bands for given conditions [dB/km] (based on [15]).

f (Hz)		63	125	250	500	1000	2000	4000	8000
HR 70 %	20˚C	0.090	0.339	1.13	2.80	4.98	9.02	22.90	76.60
	25˚C	0.077	0.030	1.06	3.08	6.19	10.40	21.90	65.40

through the propagation medium (the atmosphere). For the purposes of the calculations, a decay law (Div) as shown in Equation (7) should be considered:

$$\text{Div} = 10\log\left(\frac{d}{100}\right)^{n(f_i)}$$

$n(f_i)$ depends on the central frequency f_i of each octave band.

As aerodynamic wind turbine noise does not fulfill the main hypotheses of environmental acoustics, different depletion behavior can be expected at different frequencies. In fact, as turbulent energy dissipation is different at different frequencies, it explains the use of a set of values of $n = n(f)$ [7, 10, 12, 13] instead of only one value of n [9].

Table 4 presents the set of general values of $n_i(f_i)$ to be used when working in standard octave bands. These are also improved values referred to those from [6] and [10].

Different sets of values of $n(f_i)$ can be obtained when classifying measured data by atmospheric stability, wind speed, temperature or humidity. The most accurate results are retrieved when the set of n-values is selected by atmospheric stability or by wind speed [7].

The divergence term (Div) should be added to the previously computed sound pressure level at 100 m. Then, the sound pressure level in each octave band i at distances d greater than 100 m will be obtained as stated in Equation (8):

$$L_{p,A,d,i} = L_{p,A,100\,\text{m},i} - \Gamma_i \cdot \frac{d[\text{m}]}{1000} - 10\log\left(\frac{d[\text{m}]}{100}\right)^{n(f_i)} \quad (8)$$

Finally, the sound pressure levels obtained in each band $L_{pAd,f}$ should be logarithmically added to achieve the value $L_{pA,d}$, as stated in Equation (9):

$$L_{pA,d} = \sum_{f=16\,\text{Hz}}^{f=8000\,\text{Hz}} 10^{\frac{L_{pAdf}}{10}}$$

3.7. Assessment of the Expected Acoustic Impact

The assessment of the acoustic impact of the operation of a new wind farm can be done by different methodologies. The Guidelines to Noise Pollution Standards from the Uruguayan National Directory for the Environment (DINAMA) consider target sound pressure levels both for outdoor (see Table 5) and indoor environments (Table 6 and Table 7) [5].

The Guidelines states:

"For installing activities that are expected to increase the environmental sound pressure levels, such as industrial or agro industrial projects, extractive activities,

Table 4. General values for n(f) [7].

f (Hz)	16	31,5	63	125	250	500	1000	2000	4000	8000
n(f)	0.53	0.69	0.97	1.48	2.08	2.10	2.19	1.77	1.28	0.40

Table 5. Target values for outdoor acoustic quality (according to [5]).

	$L_{AF,eq}$ (dBA)			
	Immission (traffic noise included)		Immission (traffic noise excluded)	
	Day	Night	Day	Night
Rural areas	50	45	45	40
Urban areas	70	60	65	55

Table 6. Acceptable indoor sound pressure levels, according to its use ($L_{AF,eq}$) (according to [5]).

Use of the room	$L_{AF,eq}$ [dBA]	
Dwellings in urban/urban development areas	Day	Night
	45	35
Dwellings in rural areas	35	
Classrooms (background noise excluding that from activities performed for fulfilling their aim)	35	
Hospital wards at health care centers (background noise excluding that from activities related to patients health care performed within the room)	35	

Table 7. Acceptable indoor sound pressure levels in frequency octave bands ($L_{Z,eq}$) (according to [5]).

Central frequency of the octave band (Hz)	63	125	250	500	1000	2000	4000	8000
Acceptable L [dBZ] for $L_{AF,eq} = 35$	55	50	45	40	35	30	28	28
Acceptable L [dBZ] for $L_{AF,eq} = 40$	59	54	50	45	40	35	33	33
Acceptable L [dBZ] for $L_{AF,eq} = 45$	63	58	54	50	45	41	38	38

wind farms or wind turbines, airports, ports, roads and railways among others, a damping area should be defined. The target values for outdoor acoustic quality will not necessarily enforced in the damping area. However the permitted indoor sound pressure levels must be respected in all cases.”

The acceptable sound pressure levels for indoor dwellings are expressed both by A-weighted values $L_{AF,eq}$ and by octave bands spectra $L_{ZF,eq}$, as stated in **Table 6** and **Table 7**. The Guidelines states that the sound pressure levels in octave bands in **Table 7** should be also fulfilled. They are the PNC 35, 40 and 45 curves.

3.8. Management Measures to Be Considered to Ensure the Environmental Acoustic Quality

Depending on the results obtained when comparing the predicted sound pressure levels and the guidelines values, management measures are to be studied, presented to the authorities and then, put in practice to ensure that the acoustic quality of the area will not worsen. Among the management measures to be considered, "structural" measures shall be detailed (noise barriers, housing quality improving, etc.); also, the monitoring planning of environmental sound pressure levels and people's opinion in the area of study shall be informed.

Receivers into the EDIA would fit into one of the following three cases:

1) Values of Table 5 are met in the AIS and the sound pressure levels increase (related to the baseline) is not greater than 3 dB.

2) Values of Table 5 are met in the AIS but the sound pressure levels increase (related to the baseline) is expected to be greater than 3 dB.

3) Values of Table 5 are not met in the AIS.

In Case 1, the AIS monitoring plan for the operation phase should include measuring sound pressure levels at least once a year outdoor and indoor, at the same places measured at the base line. The measured values would be compared to the guidelines presented in Table 6 and Table 7. Carrying out the measurements during summertime is strongly recommended. If measured values endorse we are in Case 1, measuring would be repeated one year later.

In Case 2, the AIS monitoring plan for the operation phase should include measuring sound pressure levels at least twice a year (one of them during summertime) outdoor and indoor, at the same places measured at the base line. If measured values endorse that the Guidelines' values are met and there are no complaints about noise, the building would be treated in the future as a Case 1. If measured values show that the Guidelines' values are not met, the building should be treated as in Case 3. If measured values endorse the Guidelines' values are met but there are strong complaints, the measures should be repeated to decide as soon as possible how to treat the case (as Case 1 or as Case 3).

In Case 3, Guidelines' values are not expected to be met. Thus, specific mitigation measures should be designed. Noise control devices should be included as new components of the main project. Then, expected immission sound pressure levels should be computed again, both for outdoor and indoor levels. Then, the building would turn into one of the previous cases (1 or 2) and the monitoring plan is going to be designed regarding that. When noise control actions are needed, it is highly recommended to project them to reach Case 1.

4. Final Remarks

A simplified methodology for carrying out Acoustic Impact Studies of wind farms, developed for the case of Uruguay has been presented.

How to determine the direct influence area for baseline studies and for the acoustic impact base line has been stated.

A simplified method for achieving the expected sound pressure levels due to operation of wind turbines has been explained. Its outcome is more accurate than those from ISO 9613-2 Standard.

Demands of Uruguayan National Guidelines for Noise Pollution have been also detailed.

The main features for the monitoring plan for the operation phase have been introduced, taking into account the assessment of results from previous steps.

Acknowledgements

Most of our research on acoustic impact of wind turbines has been supported by the National Energy Directorate of the Ministry of Industry, Energy and Mining of Uruguay (DNE-MIEM), by the Sectorial Energy Fund of the National Agency of Research and Innovation (Project ANII_FSE_1_2013_1_10942) and CSIC I+D Program for Research Teams.

Many people have belonged to this team along many years (in alphabetical order): Fabiana Bianchi Falco, Pablo Bonilla Medina (in memoriam), Nicolás Cunha Apatie, Matteo Deambrosi Papini, Matías Hernández Castellani, Joaquín Montero Croucciée and Guillermo Sugasti Sánchez. We are especially thankful to Dr. Eng. José Cataldo for his permanent support and for generously sharing with us his wide and deep knowledge.

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