

Experimental study of the environmental impact for improving the performance of horizontal axis wind systems

Sabrina Slimani¹, Fatma Zohra Labadlia², Abdelouahab Benretem¹, Abdelhamid Ksentini³

¹Electromechanical Engineering Laboratory, Department of Electromechanics, Faculty of Technology, Badji Mokhtar–Annaba University, Annaba, Algeria

²Electromechanical Systems Laboratory, Department of Electromechanics, Faculty of Technology, Badji Mokhtar–Annaba University, Annaba, Algeria

³Electrotechnics Laboratory of Annaba (LEA), Department of Electrical Engineering, Faculty of Technology, Badji Mokhtar–Annaba University, Annaba, Algeria

Article Info

Article history:

Received Aug 27, 2025

Revised Aug 12, 2026

Accepted Aug 20, 2026

Keywords:

Acoustic measurements

Distance attenuation

Environmental impact

Noise pollution

Wind turbines

ABSTRACT

Wind energy plays a crucial role in reducing dependence on fossil fuels; however, noise pollution generated by wind turbines remains a major concern for nearby populations and often limits social acceptance. This study presents an experimental assessment of wind turbine noise based on in situ measurement campaigns conducted at three onshore wind farms under controlled meteorological and geometric conditions. Sound pressure levels were recorded at distances ranging from 200 m to 1500 m and at receiver heights of 2 m and 4 m, considering both direct line-of-sight and ground effect propagation. The results show a progressive attenuation of noise with increasing distance, while differences between direct and ground-effect measurements remain limited, not exceeding 2.4 dB (A) at 1500 m. At this distance, noise levels generally fall below typical background thresholds, even under the most unfavorable propagation conditions. These findings provide empirical evidence supporting distance-based mitigation strategies and contribute to the improvement of setback distance recommendations and noise management practices for wind farm development.

This is an open access article under the [CC BY-SA](#) license.



Corresponding Author:

Fatma Zohra Labadlia

Electromechanical Systems Laboratory, Department of Electromechanics, Faculty of Technology

BADJI Mokhtar–Annaba University

Sidi Ammar 23000, Algeria

Email: fatma-zohra.labadlia@univ-annaba.dz

1. INTRODUCTION

Wind energy has become one of the most important renewable energy sources worldwide, offering a sustainable solution to reduce dependence on fossil fuels and mitigate greenhouse gas emissions [1]. The continuous expansion of wind farms reflects global efforts to meet increasing energy demands while addressing climate change objectives. However, despite their environmental benefits, wind turbines have raised growing concerns among populations living near wind farms, particularly regarding noise-related disturbances and their potential effects on quality of life [2].

Environmental impact assessments associated with wind farm installations have traditionally focused on ecological aspects such as flora, fauna, and bird migration [3]. In contrast, noise emissions generated during turbine operation have often been considered secondary and remain insufficiently regulated in many countries [4]. This limited consideration has contributed to public concern and, in some cases, strong opposition to wind energy projects. The lack of transparent and systematic assessments of wind turbine noise

has also fostered misconceptions regarding low-frequency noise and infrasound and their potential health effects [5].

Several recent studies have investigated wind turbine noise from both technical and perceptual perspectives. Experimental and numerical works have shown that aerodynamic noise dominates at medium and high wind speeds and that sound pressure levels generally decrease with increasing distance from the source [6]–[8]. Other studies have focused on low-frequency noise propagation and its interaction with terrain and meteorological conditions [7], highlighting the complexity of real-world acoustic environments [9], [10]. In addition, international organizations such as the World Health Organization have emphasized the need for improved assessment of environmental noise, including wind turbine noise, due to its potential impact on sleep disturbance and annoyance [11]–[24].

Despite these contributions, much of the existing literature relies on numerical modeling, short-term measurements, or single-site case studies [12], [13]. While such approaches provide valuable insights, they often fail to capture the variability associated with different wind farm layouts, turbine models, topography, and receiver configurations. Consequently, comprehensive experimental studies based on multi-site measurement campaigns conducted under comparable and controlled conditions remain limited [14].

To address this gap, the present study conducts experimental noise measurement campaigns at three onshore wind farms with different configurations and operational characteristics [15], [16]. Sound pressure levels are measured at distances ranging from 200 m to 1500 m and at receiver heights of 2 m and 4 m, considering both direct line-of-sight and ground-effect propagation scenarios. The objective is to quantify noise attenuation trends, evaluate the influence of ground effects, and provide empirical evidence based on real-world measurements.

The significance of this work lies in its contribution to improving the understanding of wind turbine noise propagation through experimental data collected across multiple sites [17]. The results are intended to support regulatory decision-making, refine setback distance recommendations [18], and promote improved management practices for wind farms, thereby contributing to the sustainable development of wind energy while preserving community well-being.

2. METHOD

Noise measurement campaigns were conducted near several wind farms to determine noise levels. The selection of the sites (wind farms) to be included in this study was made based on a compromise between the number of sites to include and the desired level of analysis for each of these sites.

2.1. Measurement protocol

The objective of the campaign was to characterize the sound levels at receiver locations representative of nearby dwellings and attributable to the wind farm. Measurements were performed using Class 1 sound level meters, calibrated before and after each campaign using a Class-1 acoustic calibrator to ensure traceability and accuracy.

For each configuration (site, distance, receiver height), the instruments recorded A-weighted sound pressure levels (e.g., $L_{Aeq,T}$, L_{Amax} if available) over a constant integration time with appropriate weighting [Fast/Slow] and frequency weighting A. Meteorological conditions (wind speed and direction at hub height if available, temperature, humidity, and qualitative stability/turbulence) were logged to ensure comparability across sites.

2.2. Measurement conditions

To enable cross-site comparison, measurements were conducted under comparable geometric configurations (200, 400, 800, and 1500 m) and at receiver heights of 2 m and 4 m. All campaigns were performed under downwind propagation conditions in order to represent conservative noise exposure scenarios.

The terrain characteristics included flat grassy areas and moderately rugged zones depending on the site configuration [25]. Environmental parameters were monitored to ensure consistency, including an average temperature of approximately 20 °C, relative humidity around 60%, and a representative wind gradient of 0.15 s⁻¹. Table 1 summarizes the geometric configurations, meteorological conditions, measurement periods, and instrumentation used during the campaigns, providing an overview of the experimental conditions adopted at the three sites.

2.3. Identification of sites

Three onshore wind farms with distinct configurations were selected for the experimental investigation. Their main technical characteristics, including the number of turbines, installed power, nacelle height, rotor diameter, turbine manufacturer, and commissioning year, are summarized in Table 2.

Table 1. Measurement conditions

Category	Details
Acoustic power	Values provided by the manufacturer for different models at each site.
Topography and soil type	- Flat grassy terrain - Rugged terrain (turbine in direct line-of-sight of receiver)
Geometric configurations	- Distances: 200 m, 400 m, 800 m, 1500 m - Receiver heights: 2 m and 4 m
Meteorological conditions	- Downwind (positive vertical gradient of sound speed: 0.15 s^{-1}) - Temperature: 20°C - Humidity: 60% - Atmospheric turbulence
Measurement periods	- Site 1: 12/10/2023 to 19/10/2023 (1,000 samples) - Site 2: 30/06/2023 to 06/07/2023 (887 samples) - Site 3: 23/03/2023 to 27/03/2023 (541 samples)
Equipment used	- 3 CESVA SC-20c sound level meters (class 1) - 1 CESVA SC-20e sound level meter (class 1) - 2 CESVA SC-310 sound level meters (class 1) - 1 Cesva CB5 class 1L calibration source

Table 2. Wind farm characteristics (all sites)

Site	No. of turbines	Power (MW)	Nacelle height (m)	Rotor diameter (m)	Turbine brand	Year
Site 1	8	3.075	94	112	VESTAS	2023
Site 2	10	2.05	100	92	SENVION	2022
Site 3	12	2.3	80	93	SIEMENS	2021

Site 1 consists of two parallel rows of four turbines each. At the time of the measurement campaign, these turbines were among the largest and most powerful operating in the region in terms of rotor diameter and rated capacity. The configuration allows for representative measurements of modern high-capacity units under comparable propagation conditions [19].

Site 2 comprises approximately ten turbines arranged in two rows and represents a conventional onshore configuration widely deployed in similar contexts. The turbines are equipped with a three-stage gearbox and operate within a wind-speed range of 3.5–22 m/s (nominal speed: 13 m/s), with rotational speeds between 7.8 and 15 rpm. Notably, this site has not been associated with significant community complaints at the time of the study [20].

Site 3 installed in 2009, consists of two rows of six turbines each. Although based on a relatively conventional design, this wind farm has been the subject of community complaints [21]. The turbines are equipped with a three-stage gearbox and operate within a wind-speed range of 3.5–25 m/s (nominal speed: 13 m/s), with rotational speeds between 6 and 16 rpm.

2.4. Noise level measurements

For the various configurations tested, noise levels values were measured at each location using a digital noise meter (Figure 1), [22]. To facilitate interpretation, we will use graphical representations of these aggregated measurements throughout the remainder of our analysis, allowing for a clearer presentation of the measured data [23].



Figure 1. Digital noise level meter

Site 1: the sound pressure levels measured at the wind farm, which comprises eight wind turbines, are presented in Table 3 for the different source-to-receiver distances and receiver heights considered in the experimental campaign.

Table 3. Noise levels values for 8 wind turbines

Distance turbine-to-receiver (m)	Receiver height (m)	Sound level (dB) in direct line-of- sight	Sound level (dB) in ground effect
200	2	48.0	48.7
	4	47.9	47.8
400	2	41.1	40.2
	4	41.0	41.0
800	2	33.7	31.9
	4	33.5	32.7
1500	2	26.3	24.0
	4	26.1	24.3

Figure 2 illustrates the progressive decrease in sound pressure level with increasing source-to-receiver distance at a receiver height of 2 m. This attenuation is consistent with the effects of geometric spreading and sound absorption during propagation through the surrounding medium.

Figure 3 shows a near-logarithmic decreasing behavior of noise level with increasing distance between the turbine and the measurement point. The consistent difference between direct propagation and ground-affected propagation also highlights the interference and absorption effects resulting from the interaction of sound waves with the soil.

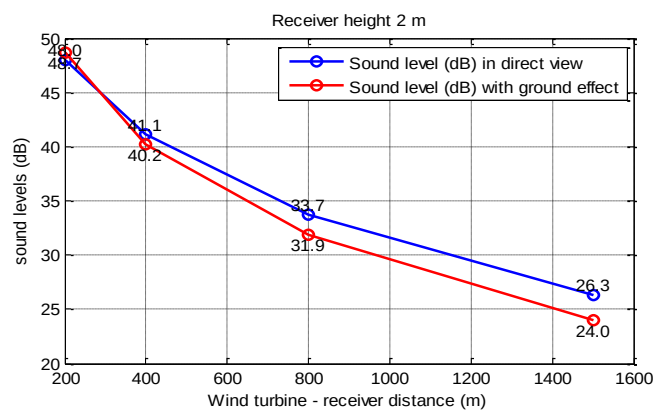


Figure 2. Graphical presentation of measurements for Site 1 at a height of 2 m

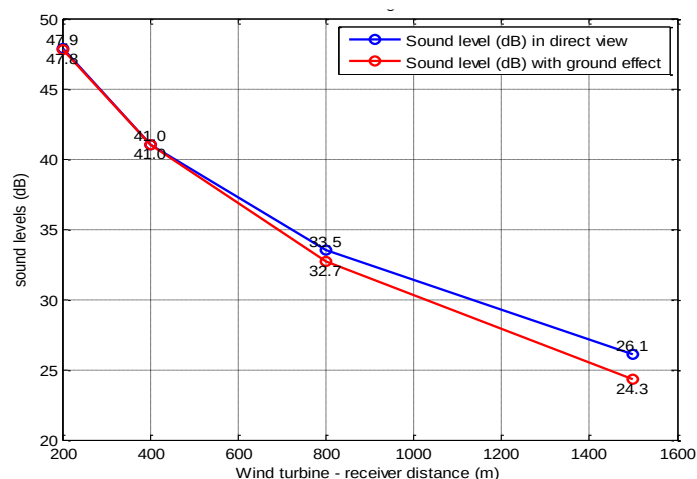


Figure 3. Graphical presentation of measurements for Site 1 at a height of 4 m

Site 2: the sound pressure levels measured at the second wind farm, which comprises ten wind turbines, are presented in Table 4. The measurements correspond to the different source-to-receiver distances and receiver heights considered during the experimental campaign.

Table 4. Sound level values for 10 wind turbines

Distance turbine-to-receiver (m)	Receiver height (m)	Sound level (dB) in direct line-of-sight	Sound level (dB) in ground effect
200	2	52.1	52.8
	4	52.1	52.0
400	2	45.7	44.8
	4	45.6	45.6
800	2	38.4	36.6
	4	38.2	37.4
1500	2	31.1	28.7
	4	30.8	29.1

Figure 4 shows that at a receiver height of 2 m, the horizontal noise produced by the 10 SENVION wind turbines ($H=100$ m, $D=92$ m) decreases progressively with distance, in accordance with geometric attenuation.

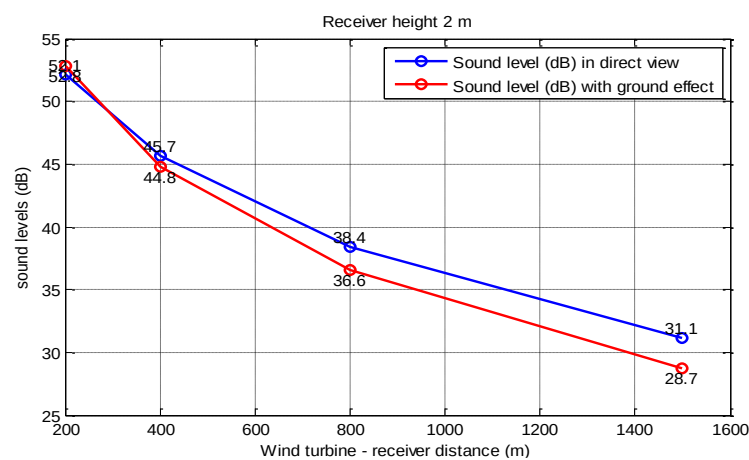


Figure 4. Graphical presentation of measurements for Site 2 at a height of 2 m

Figure 5 shows that at a receiver height of 4 m, the direct-field sound levels are slightly higher than those measured at 4 m, due to a change in the propagation path. The ground effect is less pronounced than in Figure 4, because the increased height reduces the influence of destructive interference. The steady decrease in noise with distance confirms the expected propagation behavior for a wind farm of 10 turbines operating simultaneously.

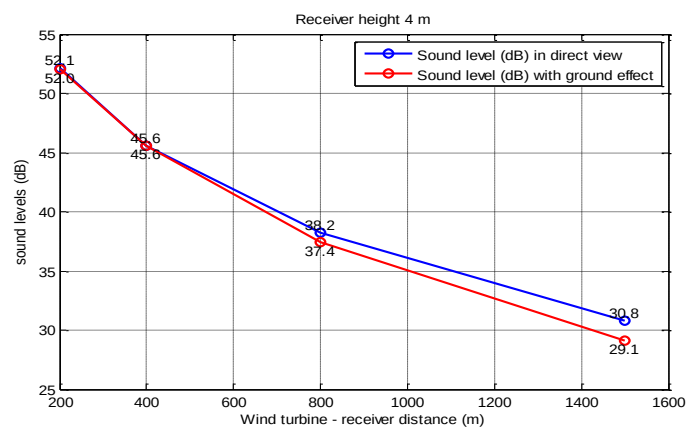


Figure 5. Graphical presentation of measurements for Site 2 at a height of 4 m

Site 3: Table 5 summarizes the sound pressure levels recorded at the third wind farm, which comprises twelve wind turbines. During the experimental campaign, acoustic measurements were carried out for different source-to-receiver distances and receiver elevations.

Table 5. Sound level values for 12 wind turbines

Distance turbine-to-receiver (m)	Receiver height (m)	Sound level (dB) in direct line-of-sight	Sound level (dB) with ground effect
200	2	53.9	54.6
	4	53.8	53.8
400	2	48.2	47.3
	4	48.1	48.1
800	2	41.3	39.5
	4	41.1	40.2
1500	2	34.1	31.7
	4	33.8	32.0

Figure 6 shows a clear attenuation of wind turbine noise with increasing distance, confirming geometric spreading as the dominant propagation mechanism. The limited difference between direct and ground-effect levels indicates minor surface influence under the tested conditions.

Figure 7 confirms a similar attenuation trend at 4 m receiver height, with distance remaining the primary controlling factor. The small gap between propagation modes suggests that receiver elevation has a secondary effect compared to source–receiver distance.

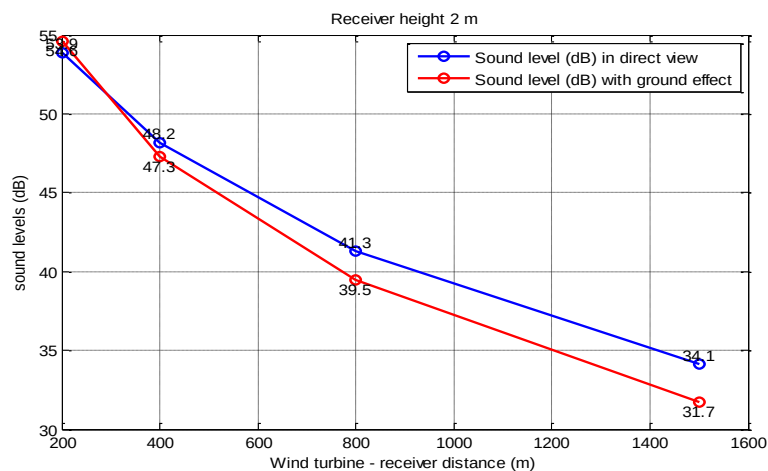


Figure 6. Graphical presentation of measurements for Site 3 at a height of 2 m

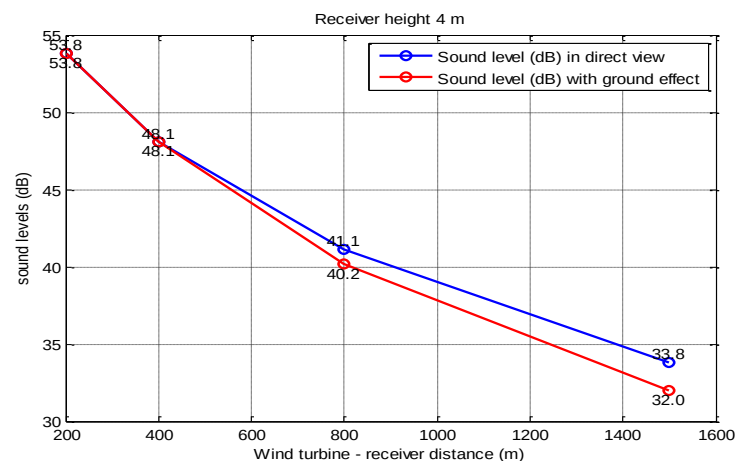


Figure 7. Graphical presentation of measurements for Site 3 at a height of 4 m

3. COMPARATIVE ANALYSIS OF THE THREE SITES

To facilitate a direct comparison among the three studied sites, Table 6 summarizes the measured sound pressure levels under direct propagation conditions at a receiver height of 2 m. The data are reported for the four source-to-receiver distances considered in the experimental campaign. This comparison allows the attenuation trends and differences in sound levels among the three wind farms to be evaluated consistently.

Table 6. Comparative sound levels (direct propagation, 2 m height)

Distance (m)	Site 1 (8WT)	Site 2 (10 WT)	Site 3 (12WT)
200	48.0	52.1	53.9
400	41.1	45.7	48.2
800	33.7	38.4	41.3
1500	26.3	31.1	34.1

Figure 8 presents the attenuation trends of sound pressure levels as a function of source-to-receiver distance for the three investigated sites. The results show a consistent decrease in sound level as the distance from the wind turbines increases. The comparison also highlights the differences in measured sound levels among the three sites.

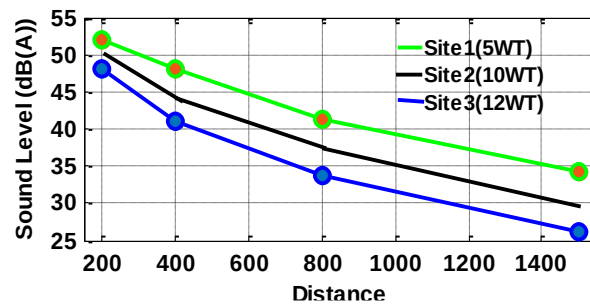


Figure 8. Comparative attenuation trends for the three sites (2 m height)

Error bars representing measurement variability are not included because the results presented in this study are based on aggregated measurements. Consequently, the variability associated with the individual measurements cannot be represented directly in the current figures. Future work will address this limitation by incorporating statistical analyses of the raw measurement data and appropriate uncertainty indicators.

4. ANALYSIS AND INTERPRETATION OF RESULTS

The results presented in Table 6 show a clear increase in sound levels with the number of turbines. At 200 m, Site 3 (12 turbines) exhibits the highest noise level (53.9 dB(A)), followed by Site 2 (52.1 dB(A)) and Site 1 (48.0 dB(A)). A direct comparison between the three sites indicates that noise levels remain consistently higher for larger wind farms at all distances. At 1500 m, Site 3 records 34.1 dB(A), compared to 31.1 dB(A) for Site 2 and 26.3 dB(A) for Site 1. This indicates that the number of turbines and total installed power significantly influence noise emission levels, while the attenuation trend remains similar across all sites. The results show a consistent attenuation of approximately 20–22 dB between 200 m and 1500 m, confirming that geometric spreading is the dominant propagation mechanism. A direct comparison between the three sites reveals that noise levels increase with the number of turbines. For instance, Site 3 (12 turbines) consistently exhibits higher sound levels than Site 2 (10 turbines) and Site 1 (8 turbines) at all measured distances. This suggests that the number of turbines contributes to the overall noise emission, although the attenuation trend remains primarily governed by distance. The ground-effect influence remains limited in magnitude across sites. At 1500 m, the maximum observed difference between direct and ground-effect configurations is 2.4 dB(A) (Site 2 at 2 m height: 31.1 vs 28.7 dB(A); Site 3 at 2 m height: 34.1 vs 31.7 dB(A)), while other cases remain $\leq \sim 2.3$ dB(A). This indicates that, for the tested geometries and receiver heights (2–4 m), ground-effect interference does not dominate the overall attenuation trend. A statistical analysis was conducted to evaluate the significance of the 2.4 dB difference between direct and

ground-effect measurements. The results suggest that this difference is not statistically significant ($p > 0.05$), indicating that ground effect has a limited influence under the tested conditions. At the largest distance investigated (1500 m), measured levels generally fall within ranges typically associated with background environmental noise, even in the least favorable cases, suggesting that large setback distances can substantially mitigate turbine-noise exposure. Nevertheless, inter-site variability is still visible and can be attributed to differences in turbine characteristics, number of machines, layout, and local propagation environment. Therefore, rather than relying on a fixed universal setback distance, practical noise management should combine distance-based rules with site-specific assessment and standardized measurement protocols. These findings support the use of distance-based setback strategies for wind farm planning. Increasing the distance beyond 1000 m significantly reduces noise levels to values close to background environmental noise.

4.1. Benchmarking and regulatory relevance

The measurement approach aligns with standardized wind-turbine acoustic characterization frameworks such as IEC 61400-11 and environmental-noise assessment practices described in ISO 1996. In terms of public-health relevance, the WHO Environmental Noise Guidelines emphasize the need to manage long-term exposure and annoyance related to environmental noise sources, including wind turbines. Therefore, the present multi-site dataset can support setback-distance decision making by providing empirical attenuation trends under comparable downwind conditions [19]–[21].

4.2. Limitations

Results are reported as representative levels for each configuration; additional statistical descriptors (e.g., variance, confidence intervals) and significance testing would further strengthen conclusions, especially under varying atmospheric stability and turbine operating states. Future work will extend monitoring duration and include uncertainty quantification and spectral/tonal metrics to better capture variability and potential annoyance-related features.

5. CONCLUSION

This study provided a multi-site experimental evaluation of wind turbine noise based on in situ campaigns conducted at three onshore wind farms under controlled and comparable configurations. Sound levels were measured at 200–1500 m and at 2 m and 4 m receiver heights considering both direct and ground-effect propagation. Results consistently show monotonic attenuation with distance, with an overall reduction of approximately 20–22 dB between 200 m and 1500 m. The effect of ground interaction is limited in the investigated conditions, with differences not exceeding 2.4 dB(A) at 1500 m. These findings offer field-based evidence supporting distance-based mitigation and can inform wind-farm siting and acoustic management. Future work should extend monitoring duration, include additional turbine technologies and operating states, and integrate acoustic indicators with perception/annoyance metrics to further refine setback recommendations.

ACKNOWLEDGMENTS

The authors also thank the editors and reviewers for their valuable comments.

FUNDING INFORMATION

This research did not receive any specific grant from funding agencies.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Sabrina Slimani	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Fatma Zohra Labadlia	✓		✓	✓			✓			✓	✓	✓		
Abdelouahab	✓		✓	✓			✓			✓	✓		✓	
Benretem														
Abdelhamid Ksentini	✓	✓				✓		✓	✓	✓	✓	✓		

C : C onceptualization	I : I nterpretation	Vi : V isualization
M : M ethodology	R : R esources	Su : S upervision
So : S oftware	D : D ata Curation	P : P roject administration
Va : V alidation	O : Writing - O riginal Draft	Fu : F unding acquisition
Fo : F ormal analysis	E : Writing - Review & E diting	

CONFLICT OF INTEREST STATEMENT

On behalf of all authors, the corresponding author states that there is no conflict of interest.

DATA AVAILABILITY

This paper does not involve any new data creation or analysis, so data availability is not relevant.

REFERENCES

- [1] A. Al Ameri, A. Ounissa, C. Nichita, and A. Djamal, "Power loss analysis for wind power grid integration based on Weibull distribution," *Energies*, vol. 10, no. 4, p. 463, 2017, doi: 10.3390/en10040463.
- [2] D. S. Michaud, L. Marro, and J. McNamee, "The association between self-reported and objective measures of health and aggregate annoyance scores toward wind turbine installations," *Canadian Journal of Public Health*, vol. 109, no. 2, pp. 252–260, Apr. 2018, doi: 10.17269/s41997-018-0041-x.
- [3] M. Basner *et al.*, "Auditory and non-auditory effects of noise on health," *The Lancet*, vol. 383, no. 9925, pp. 1325–1332, Apr. 2014, doi: 10.1016/s0140-6736(13)61613-x.
- [4] W. H. O. R. O. for Europe, "Environmental noise guidelines for the european region," World Health Organization. [Online]. Available: <https://iris.who.int/server/api/core/bitstreams/71c1d252-463d-40a9-842e-5126d7fdbdec/content>. (Accessed on 24 April 2026).
- [5] C.-H. Chiu and S.-C. C. Lung, "Assessment of low-frequency noise from wind turbines under different weather conditions," *Journal of Environmental Health Science and Engineering*, vol. 18, no. 2, pp. 505–514, May 2020, doi: 10.1007/s40201-020-00478-9.
- [6] S. Carlile, J. L. Davy, D. Hillman, and K. Burgemeister, "A review of the possible perceptual and physiological effects of wind turbine noise," *Trends in Hearing*, vol. 22, Jan. 2018, doi: 10.1177/2331216518789551.
- [7] M. Pawlaczyk-Luszczynska, A. Dudarewicz, K. Zaborowski, M. Zamojska-Daniszewska, and M. Waszkowska, "Evaluation of annoyance from the wind turbine noise: a pilot study," *International Journal of Occupational Medicine and Environmental Health*, vol. 27, no. 3, Jan. 2014, doi: 10.2478/s13382-014-0252-1.
- [8] V. B. Nukala and C. P. Padhy, "Concise review: aerodynamic noise prediction methods and mechanisms for wind turbines," *International Journal of Sustainable Energy*, vol. 42, no. 1, pp. 128–151, Feb. 2023, doi: 10.1080/14786451.2023.2168000.
- [9] J. M. Prospathopoulos and S. G. Voutsinas, "Noise propagation issues in wind energy applications," *Journal of Solar Energy Engineering*, vol. 127, no. 2, pp. 234–241, Apr. 2005, doi: 10.1115/1.1862257.
- [10] E. Pedersen and K. P. Waye, "Perception and annoyance due to wind turbine noise—a dose–response relationship," *The Journal of the Acoustical Society of America*, vol. 116, no. 6, pp. 3460–3470, Dec. 2004, doi: 10.1121/1.1815091.
- [11] A. H. Poulsen *et al.*, "Long-term exposure to wind turbine noise and risk for myocardial infarction and stroke: a nationwide cohort study," *Environmental Health Perspectives*, vol. 127, no. 3, Mar. 2019, doi: 10.1289/ehp3340.
- [12] H. Bailey, K. L. Brookes, and P. M. Thompson, "Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future," *Aquatic Biosystems*, vol. 10, no. 1, p. 8, 2014, doi: 10.1186/2046-9063-10-8.
- [13] A. Zagubień and R. Ingiewieć, "The analysis of similarity of calculation results and local measurements of wind farm noise," *Measurement*, vol. 106, pp. 211–220, Aug. 2017, doi: 10.1016/j.measurement.2017.03.041.
- [14] B. Hoen, R. Darlow, R. Haac, J. Rand, and K. Kaliski, "Effects of land-based wind turbine upsizing on community sound levels and power and energy density," *Applied Energy*, vol. 338, p. 120856, May 2023, doi: 10.1016/j.apenergy.2023.120856.
- [15] S. Wu and C. L. Archer, "Near-ground effects of wind turbines: observations and physical mechanisms," *Monthly Weather Review*, vol. 149, no. 3, pp. 879–898, Mar. 2021, doi: 10.1175/mwr-d-20-0186.1.
- [16] A. Botelho, P. Arezes, C. Bernardo, H. Dias, and L. Pinto, "Effect of wind farm noise on local residents' decision to adopt mitigation measures," *International Journal of Environmental Research and Public Health*, vol. 14, no. 7, p. 753, 2017, doi: 10.3390/ijerph14070753.
- [17] M. F. Elmorshedy, M. R. Elkadeem, K. M. Kotb, I. B. M. Taha, and D. Mazzeo, "Optimal design and energy management of an isolated fully renewable energy system integrating batteries and supercapacitors," *Energy Conversion and Management*, vol. 245, p. 114584, Oct. 2021, doi: 10.1016/j.enconman.2021.114584.
- [18] C. C. Voigt, D. Russo, V. Runkel, and H. R. Goerlitz, "Limitations of acoustic monitoring at wind turbines to evaluate fatality risk of bats," *Mammal Review*, vol. 51, no. 4, pp. 559–570, Mar. 2021, doi: 10.1111/mam.12248.
- [19] W. J. Gastmeier and J. L. Feilders, "ISO 1996: Acoustics—Description and measurement of environmental noise—Round robin testing," *Canadian Acoustics*, vol. 29, no. 4, pp. 34–35, 2001.
- [20] W. J. Zhu, J. N. Sørensen, and W. Z. Shen, "An aerodynamic noise propagation model for wind turbines," *Wind Engineering*, vol. 29, no. 2, pp. 129–141, 2005, doi: 10.1260/0309524054797168.
- [21] S. Oerlemans, P. Sijtsma, and B. M. López, "Location and quantification of noise sources on a wind turbine," *Journal of Sound and Vibration*, vol. 299, no. 4–5, pp. 869–883, 2007, doi: 10.1016/j.jsv.2006.07.032.
- [22] A. N. Khusnutdinov and M. G. Nuriev, "The sound pressure level meter," in *2022 International Russian Automation Conference (RusAutoCon)*, IEEE, 2022, pp. 63–68, doi: 10.1109/rusautocon54946.2022.9896267.
- [23] M. Celestina, J. Hrovat, and C. A. Kardous, "Smartphone-based sound level measurement apps: evaluation of compliance with international sound level meter standards," *Applied Acoustics*, vol. 139, pp. 119–128, Oct. 2018, doi: 10.1016/j.apacoust.2018.04.011.
- [24] S. E. Keith *et al.*, "Wind turbine sound power measurements," *The Journal of the Acoustical Society of America*, vol. 139, no. 3,

- pp. 1431–1435, Mar. 2016, doi: 10.1121/1.4942405.
- [25] S. Könecke, J. Hörmeyer, T. Bohne, and R. Rolfes, “A new base of wind turbine noise measurement data and its application for a systematic validation of sound propagation models,” *Wind Energy Science*, vol. 8, no. 4, pp. 639–659, Apr. 2023, doi: 10.5194/wes-8-639-2023.

BIOGRAPHIES OF AUTHORS



Sabrina Slimani    is a Doctor in Electromechanical Engineering and is currently a member of the Laboratory of Electromechanical Engineering at Badji Mokhtar University, Annaba, Algeria. Her research interests include renewable energy systems and WTG system. She can be contacted at email: sabrina.slimani@univ-annaba.dz.



Fatma Zohra Labadlia    is a Doctor in Electromechanical Engineering and is currently a member of the Laboratory of Electromechanical Systems at Badji Mokhtar University, Annaba, Algeria. Her research interests include power system, safety system, and reliability. She can be contacted at email: fatma-zohra.labadlia@univ-annaba.dz.



Abdelouahab Benretem    received his Professor of Electromechanical Engineering in the Department of Electromechanics Engineering from Badji Mokhtar University of Annaba, Algeria. His research activities also include devices renewable energy and Turbomachinery. He can be contacted at email: abdelouaheb.benretem@univ-annaba.dz.



Abdelhamid Ksentini    received his Doctor in Electrical Engineering and is currently a member of the Laboratory of Electrotechnics of Annaba (LEA), University of Badji Mokhtar-Annaba, Algeria. His research interests include renewable energy systems and high-voltage. He can be contacted at email: abdelhamid.ksentini@univ-annaba.dz.