Pol. J. Environ. Stud. Vol. 23, No. 4 (2014), 1323-1327

Short Communication

Infrasound Noise of Natural Sources in the Environment and Infrasound Noise of Wind Turbines

Ryszard Ingielewicz*, Adam Zagubień**

Faculty of Civil Engineering, Environmental and Geodetic Sciences, Koszalin University of Technology,
Śniadeckich 2, 75-453, Koszalin, Poland

Received: 12 September 2013
Accepted: 2 April 2014

Abstract

This article presents the results of measurements of environmental noise in respect to infrasounds. Infrasound sources whose levels depend on wind speed have been analyzed. The measurements were done for two common natural sources in the environment: forest noise and sea waves, and for an artificial (technical) source: wind turbines.

On the basis of results of measurements we have made an attempt of assessment of potential threat to people. Drawing conclusions from analyses it can be said that infrasound noise levels emitted by wind turbines do not reach levels causing threat to people; they can be compared to natural sources noise levels, common in environment.

Keywords: noise measurements, infrasound, wind turbines

Introduction

Infrasounds are common in the natural environment. There are many opinions about their harmfulness, especially when it comes to one of the main energy sources: wind turbines using wind power. We can find a large description of the influence and potential harm of infrasound noise – among others – in publications [1, 2]. The noise emitted during wind turbine operation is of audible frequencies from 20 to 20,000, and also the noise of infrasound character, referred to as inaudible, from 1 to 20 Hz. Such emissions may be of potential harm in cases when it reaches sufficiently high levels, mostly described as permissible levels. The description of ways of generating acoustic waves by wind turbines can be found in many studies [3].

If levels of acoustic pressure are high enough, infrasounds are detected by the ear and vestibular system. The lower the frequency of infrasounds, the higher the limits of their audibility – e.g. for frequency 6÷8 Hz it is about 100 dB, for frequency 12÷16 Hz it is about 90 dB. Moreover, besides a specific auditory method, infrasounds are detected by sensory receptors responsible for sensing vibrations placed all over the body. It is estimated that such perception levels are of 20÷30 dB higher than audible levels. Infrasounds are characterized by a very large wavelength (much more than 17 meters), which is why they are weakly attenuated and may spread over long distances.

There are two types of infrasound source: natural (beyond human activity) and artificial (technical, caused by human activity). Natural sources include the sound of the wind and all sounds caused by it (trees noise, wind whirling on obstacles, sea waves, waterfalls, thunderstorms, volcanic eruptions, etc.). Technical sources include rotating machines (e.g. compressors) combustion air-conditioning and ventilation devices, dry-well pumping stations, gas pressure-reducing stations, low-speed internal-combustion high-pressure engines, internal combustion electrical generators, jet and

*e-mail: wibrotest@wp.pl
**e-mail: adam.zagubien@tu.koszalin.pl

rocket engines, moving vehicles, line sources such as transport routes (together with their infrastructure), wind turbines, and much more.

There are no applicable reference methods describing how to measure infrasound noise in Poland. Therefore, guidelines of reference methods for environmental noise measurements within the audible range have been taken into consideration during measurements. Also, there are no legal regulations or norms defining acceptable noise levels in natural environment as far as infrasound noise emission is concerned. But this fact does not allow us to neglect the duty to monitor the dangers – we learn to take responsibility for the natural environment all life [4].

There is a current norm [5] defining the rules of measurement and so-called nuisance criteria for workplaces. Equivalent levels constituting nuisance criteria are 102 dB (86 dB for workplaces requiring special concentration) as regards 8 working hours (of working week), with measurements according to corrective curve G [6]. Those values do not constitute the basis for assessment of infrasound noise threat in the natural environment [7].

In some countries there have been attempts to limit exposure to infrasound noise (caused by external sources) in premises and dwelling houses [8]. For example, the Danish Environmental Protection Agency (DEPA) suggests that levels of exposure to infrasound noise should be 10 dB lower than infrasound audibility limits. According to Jakobsen [9], adjusted by characteristic G, the audibility limit for people of special sensitivity is 95 dB; so DEPA recommends that the total average level adjusted by frequency characteristics G within the range up to 20Hz in premises should not exceed 85dB during day and night.

Experimental Procedures

All measurements were conducted using a microphone with a windproof cover and a DSA-50 portable sound analyzer. DSA-50 is a complex sound measuring instrument. This device functions as an integrating sound level meter, an octave analyzer, and a 1/3-octave analyzer. The meter has first-class accuracy, and applying digital processing of measured sound enables measurements of most noise parameters at the same time. The meter is equipped with a mode of infra G filter and is adjusted to infrasound measurements according to the norm [6]. The microphone has linear characteristics in the range of 2 Hz to 10,000 Hz.

Measurements on a Wind Farm of 25 Vestas V80 2.0 MW Turbines and Tower Height 100 m

The measurements of infrasound noise levels were conducted in June 2011. The measurements were conducted on a wind farm consisting of 25 Vestas V80 2.0 MW turbines, 100 m tower height, while all turbines were in operation. Meteorological conditions controlled during measurements by our own meteorology station met the required criteria – the average wind speed at the height of microphone level did not exceed 5.0 m/s. At the height of the turbines' axis (100 m) the wind speed was 9.0-11.0 m/s. Two measurement series were done. First at measuring point P1 situated 3.0 m away from the axis of a turbine tower located in the central part of the farm and 1.5 m above ground level. There was a national road with heavy traffic with two lines of high trees about 100 m from this point. The second series were conducted in point P2, 500 m from a turbine situated on the edge of the farm, near a school building – 3.0 m from its wall, 1.5 m above ground level. Situating the measuring point at 1.5 m height and proper location enabled maintaining average wind speed levels – 5.0 m/s – at the height of the microphone. There was a local road about 50 m from point P2 and about 150 from it there was also a national road with heavy traffic and two lines of high trees. Time of measurement of one sample – minding stabilized level of noise emission and the possibility of excluding noticeable disturbances (passing vehicles) – was 1 minute at point P1 and 5 minutes at point P2. The results of the measurements in points P1 and P2 are presented in Table 1.

Table 1. Results of measurements, wind farm – 25 Vestas turbines.

Point No.	Measurement No.	Result of the measurement L_{Gt} [dB]	Average sound level L_{Geq} [dB]	Expanded uncertainty for confidence level 95% (U_{R95})	Final result L_{Geq} [dB]
P1	1	8.3	88.8	1.8	88.8±1.8
	2	88.9			
	3	88.2			
	4	87.7			
	5	87.0			
P2	1	67.6	66.9	1.7	66.9±1.7
	2	66.2			
	3	67.1			
	4	66.8			

Results of Own Research of Natural Infrasound Sources Caused by Wind

Measurements were conducted for typical, commonly existing in nature, natural phenomena and noise sources caused by blowing wind of speed similar to values typical of maximum acoustic power levels of wind turbines.

Infrasound Noise Measurements Caused by Forest Sound

The measurements were conducted in February 2012, in four characteristic points of a housing area adjacent to the forest (height of trees about 20-25 m) in the area which enables keeping meteorological conditions recommended in the current reference method for environmental noise measurements within audible range. During measurements, the wind speed at 10 m measured by the national meteorology station – situated 2 km away – was 9.5 to 10.5 m/s, which corresponds to maximum acoustic power levels of wind turbines. Information regarding sound power level of turbines depending on wind speed are given (by the manufacturer) for wind speed exactly at the height of 10 meters. During measurements the controlled speed of wind measured by our own station at microphone height was 2.8-4.6 m/s; wind direction – from points to the forest. There were three measuring samples in each point and the measuring time of each one was 5 minutes. Point P1 was situated in the house, 0.5 m from the closed window (typical PCV type), Point P2 was situated outside, below the slope level, 2 m from the house wall. Point P3 was also outside, below the slope level, 12 m from the house wall. Point P4 was situated outside on the slope, 32 m from the house wall and 1 m from the forest. The microphone was placed on a tripod, 1.5 m above ground level. The nearest wind farm was located 25 km from the place of conducting measurements. Fig. 1 presents a site drawing of the area of conducted measurements. Final results of the measurements are shown in Table 2.

Measurements of Noise Caused by Sea Waves

Measurements were conducted in June 2012 in three characteristic points in the housing area adjacent to a seaside dune, in an area that enables keeping meteorological conditions as recommended in the current reference method for environmental noise measurements within audible range. During measurements, the wind speed at 10 m measured by a national station 5 km away was 9.5 to 11.0 m/s, which corresponds to maximum sound power levels of wind turbines. During measurements the controlled speed of wind measured by our own station at microphone height was 2.9-4.8 m/s; wind direction – from the sea to the points. There were three measuring samples in each point and the measuring time of each was 5 minutes. Point P1 was situated in the house, 0.5 m from the closed window (typical PCV type). Point P2 was situated outside, below the slope level, between the dune and the house, 2 m from the house wall. Point P3 was also outside, on the slope, 14 m from the house wall, among low trees and bushes growing on the slope, 25 m from the seashore. The microphone was placed on a tripod 1.5 m above ground level. The nearest wind farm was located 7 km from the place of conducting measurements. Fig. 2 presents a site drawing of the area of conducted measurements. Final results of the measurements are shown in Table 3.

Table 2. Results of noise measurements caused by the sound of forest.

Measuring point No.	Average level of measurement L_{Geq} [dB]	Calculated uncertainty for confidence level 95% (U_{R95})
1	59.1	±1.5
2	72.2	±1.6
3	75.4	±1.6
4	87.8	±1.7

Results and Discussion

On the basis of obtained measurements we may draw the conclusion that infrasound noise from wind turbines is

Table 3. Results of noise measurements caused by sea waves.

Measuring point No.	Average level of measurement L_{Geq} [dB]	Calculated uncertainty for confidence level 95% (U_{R95})
1	64.3	±1.5
2	76.1	±1.7
3	89.1	±1.8

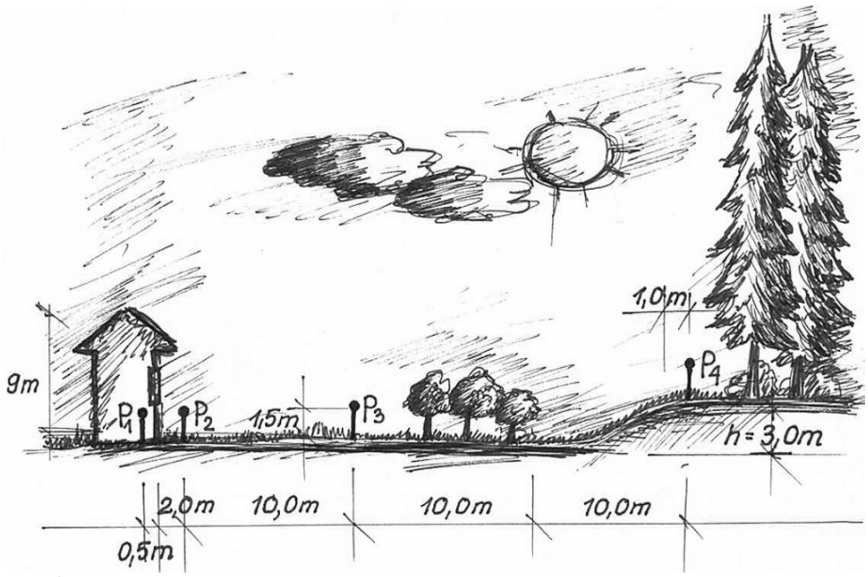

Fig. 1. Sketch of the area of measurements.

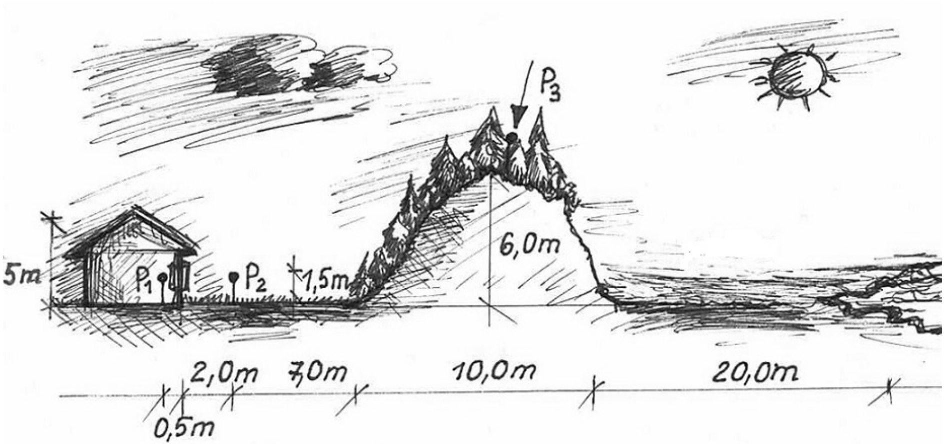

Fig. 2. Sketch of the area of measurements.

comparable to noise levels coming from typical natural noise sources. Natural noise sources – more or less – always accompany the work of wind turbines and in such cases they constitute an acoustic background, impossible to eliminate during noise measurements of wind turbines. It also has been noticed that measured levels were dependent on momentary gusts of wind. This fact is confirmed by research results conducted around different wind farms [2, 10-15].

Measurements on Wind Farm Consisting of 25 Vestas V80 2.0 MW Turbines, Tower Height 100 m

Finally, measured levels of infrasound noise immision at the turbine tower, with 25 turbines in operation together with acoustic background (sound of trees and road traffic), was:

- in point P1 – L_{Geq} = 88.8 ±1.8 dB
- in point P2 – L_{Geq} = 66.9 ±1.7 dB

Conclusions

While doing measurements and analyzing results of research when it comes to wind turbines and all other sources, under the influence of strong wind we should take into consideration the following points:

- The result of a measurement is always a result of the noise of analyzed source and an acoustic background arising from phenomena connected with gusts of wind, whose share depends on the location of the measuring point and its surroundings.
- Minding the characteristics of infrasound noise (long wave, spreading to big lengths, smaller attenuation on obstacles), the result of the measurement, in many cases, takes into account the influence of other non-identified sources of infrasound noise.
- As far as infrasound noise measurements in natural environment are concerned, Poland has no specified reference methods for conducting such measurements. Despite this fact, while conducting such measurements one should consider the current reference method of measurement of audible noise; though it seems justified to place a measuring point 1.5 m above ground level to make it easier to keep average wind speed up to 5 m/s at the microphone level.
- According to Danish recommendations [9], acceptable infrasound levels – including those from wind turbines – at places of residence, in rooms, classes, and offices is 85,0 dB (G) both during day and night time. The results of infrasound noise research from wind turbines in areas dwelled by people are of lower levels than the ones stated by Danish criteria.
- Finally, minding our own research [11], analysis and studies of other teams of experts in the world widely described in works [2] and [10, 12, 15], and the criteria of infrasound noise assessment in natural environment in different countries [5, 8, 9], it may be concluded that infrasound noise levels emitted by wind turbines do not reach levels causing a threat to people, and that they are comparable to levels of natural acoustic background common in the environment.

References

1. PAWLACZYK-ŁUSZCZYŃSKA M., DUDAREWICZ A., WASZKOWSKA M., SZYMCZAK W., KAMEDUŁA M., ŚLIWIŃSKA-KOWALSKA M. The effect of low frequency noise on human mental performance. Med. Pr. **55**, (1), 63, **2004**.
2. BILSKI B. Factors Influencing Social Perception of Investments in the Wind Power Industry with an Analysis of Influence of the Most Significant Environmental Factor – Exposure to Noise. Pol. J. Environ. Stud. **21**, (2), 289, **2012**.
3. WEGNER S., BAREISS R., GUIDATI G. Wind Turbine Noise. Springer, Berlin, **1996**.
4. PIECUCH I., PIECUCH T. Teaching About the Environment – It Is Never too Early and It Is Never too Late. Annual Set The Environment Protection. **13**, 711, **2011** [In Polish].
5. PN-Z 01338:2010 Acoustics – Measurement and assessment of infrasonic noise at work stations. **2010** [In Polish].
6. PN-ISO 7196:2002 Acoustics – Frequency-weighting characteristic for infrasound measurements. **2002**.

7. BOCZAR T., MALEC T., WOTZKA D. Studies on Infrasound Noise Emitted by Wind Turbines of Large Power. Acta Phys. Pol. A. **122**, (5), 850, **2012**.
8. JABBEN J., VERHEIJEN E.: Options for Assessment and Regulation of Low Frequency Noise. J. Low Freq. Noise V. A. **31**, (4), 225, **2012**.
9. JACOBSEN J. Danish guidelines on environmental low frequency noise, infrasound and vibration. J. Low Freq. Noise V. A. **20**, (3), 141, **2001**.
10. Massachusetts Department of Environmental Protection, Massachusetts Department of Public Health, Wind Turbine Health Impact Study: Report of Independent Expert Panel, Massachusetts, January **2012**.
11. INGIELEWICZ R., ZAGUBIEŃ A. The infrasound noise measurement emitted by wind farm. Measurement Automation and Monitoring. **59**, (7), 725, **2013** [In Polish].
12. PIERZGA R., BOCZAR T., WOTZKA D., ZMARZŁY D. Studies on Infrasound Noise Generated by Operation of Low-Power Wind Turbine. Acta Phys. Pol. A. **124**, (3), 542, **2013**.
13. MALEC T., BOCZAR T. Analysis of infrasound noise emitted by high-power wind turbine with synchronous generator. Conference Proceedings of 12'h International Conference on Environment and Electrical Engineering. Wroclaw, POLAND, 5-8 May 2013 on CD, paper No. 125, **2013**.
14. YANG K., BOLLEN M., LARSSON A., WAHLBERG M. Measurements of harmonic emission versus active power from wind turbines. Electr. Pow. Syst. Res. **108**, 304, **2014**.
15. PIERZGA R., BOCZAR T. Analysis of low-frequency acoustic signals emitted by low-power vertical axis wind turbine VAWT. Conference Proceedings of 12th International Conference on Environment and Electrical Engineering. Wroclaw, POLAND, 5-8 May 2013 on CD, paper No. 124, **2013**.