Long-term measurement of noise immission from wind turbines

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Summary
Immission measurement of wind turbine noise is usually conducted using short-term measurements during a period of strong wind speed and full power output. However, the reliability of such noise immission results has been questioned by some researchers, residents and authorities. The aim of this study was to investigate long-term variation of sound pressure levels in a yard near a wind power area. The distance to the nearest wind turbine was 650 meters. The study period was over 5 months. The long-term measurement result attempted to determine the mean sound level, $L_{A,eq}$, during the periods of maximum power output. The long-term measurement results did not involve the background noise correction so that the result was an overestimate of the true value. Despite of that, the long-term measurement result was in agreement both with the predicted $L_{A,eq}$ and with the measured $L_{A,eq}$ obtained by a short-term measurement in the same yard by an independent consulting company. The findings give no reason to doubt the validity of short-term measurements in this yard. However, further long-term measurements may be needed to validate our findings.

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1. Introduction

Sound pressure level (SPL) measurements for the determination of noise immission of wind turbines (WT) are short-term measurements accomplished during a period of high speed wind from the direction of the WTs. The wind speed should be within 6 and 10 m/s at 10 m height which means that the power output of the turbines is very close to maximum value. The detailed procedure is described in Finnish measurement guide [1]. The reliability of noise immission results measured according to the guide have been questioned by some residents, researchers and authorities because the results represent only the conditions during the specified measurement time which may not represent the greatest sound emission.

The aim of our study was to investigate long-term variation of sound pressure levels in a yard near 12 WTs. The purpose was to find out, how well the short-term measurements represented the sound pressure levels measured in the yard during the periods of maximum power output.

2. Materials and Methods

The measurement site (Figure 1) was located in a yard at a distance of 650 m to the nearest WT. The noise immission had been measured in 2014 according to the Finnish guide [1]. The A-weighted equivalent SPL, $L_{A,eq}$, was 44 dB in the yard. The result involved background noise correction and it was determined by another company [2].

The wind power area consists of 12 WTs of 4500 kW electric power production capacity (Figure 2). The WTs' rotor centre is at 140 m high and the rotor diameter is 128 m. The declared A-weighted sound power level of the WTs was 108.6 dB. The noise levels in the area had been predicted using commercial software. The predicted $L_{A,eq}$ on the measurement site was 44 dB [3].

Figure 1. The measurement microphone was mounted on the façade wall facing the wind power area (top). A view from the roof of the house towards the WTs (bottom).

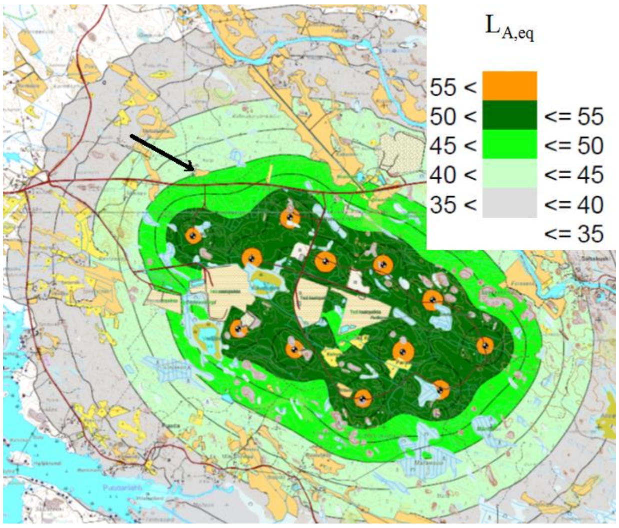

Figure 2. Map of the predicted noise levels on the area. The predicted $L_{\mathrm{A,eq}}$ on the measurement site (arrow) was 44 dB.

We conducted the long-term measurements from august 2015 to January 2016, in total 5 months and 5 days. The house was not inhabited during the measurements. However, some persons made short occasional visits to the location.

SPL was measured using a sound level meter (Norsonic NOR140). The measurement microphone (Norsonic NOR1225) was equipped with a double-layer wind screen (Microtech Gefell GFM920). The microphone was mounted on the façade wall facing to the WTs. The reported SPLs involve a -6 dB correction due to the wall reflection [4]. SPL was logged in 125 ms resolution in one-third octave bands 20–20000 Hz. The clock of the sound level meter was synchronized with the clock of the environmental measurement instrument.

The weather conditions were logged using sensors mounted on top of the WT. Mean wind speed, mean wind direction and mean power output of each WT was received from the operator every 10 minutes.

There was a road with a speed limit of 80–100 km/h at the distance of 175 m from the measurement site. The daily number of vehicles per day was 900 out of which 20% were heavy vehicles. Therefore, the $L_{\mathrm{A,eq}}$ of road traffic noise in the yard was approximately 40–45 dB during daytime and 30–35 dB during night time. A single bypass of a vehicle masked the WT sound for several seconds. Background noise was also caused by natural sources like animals and wind-induced noise. The intermittent background noise was the principal reason for the exclusion of data.

First, equivalent A-weighted SPL for 2-second-periods, $L_{\mathrm{A,eq,2s}}$ was determined. Thereafter, equivalent A-weighted SPL for 10-minute-periods, $L_{\mathrm{A,eq,10min.}}$ was determined. Three exclusion criteria were applied.

I. False data. We excluded 10-min periods known to include false data. The reason could be a visitor in the measurement site or lack of data due to e.g. power failure or maintenance break of the WTs.

II. Unusual spectrum. We excluded 10-min periods involving too much high frequency sound according to Ref. [5]:

$$L_{\mathrm{A,eq,10min}} - L_{\mathrm{A,HI,eq,10min}} > 4\ \mathrm{dB}, \quad (1)$$

where $L_{\mathrm{A,eq,10min}}$ was the A-weighted SPL within 20–20 000 Hz and $L_{\mathrm{A,HI,eq,10min}}$ was the A-weighted SPL within 800–20 000 Hz. The presumption was that 10-min-periods containing an excessive proportion of sound at frequencies above 800 Hz did not represent noise from the WTs. These samples more probably contained sounds of animals or road traffic noise (tyre noise).

III. Unusual temporal variability. We excluded 10-min periods involving too high variability according to Ref. [5]:

$$L_{\mathrm{A5}} - L_{\mathrm{A95}} < 4\ \mathrm{dB}, \qquad (2)$$

where L_{A5} and L_{A95} were the percentile levels of 5% and 95% of A-weighted SPLs, respectively. The percentile levels were determined by analyzing the 300 samples of $L_{\mathrm{A,eq,2s}}$ within each 10-min-period. The presumption was that periods containing too strong variation did not represent WT noise. These samples contained more probably traffic noise from passing vehicles or sounds of animals.

3. Results

The power production of the nearest WT in respect of wind speed at the height of 140 m during the measurement period of 5 months is presented in Figure 3. Each circle represents one sample of 10-minute-period. The total number of samples was *N*=21850. The electric power production of the nearest WT was at least 4000 kW in 8% of the 5 month measurement samples. The maximum sound power level was expected to occur within these samples.

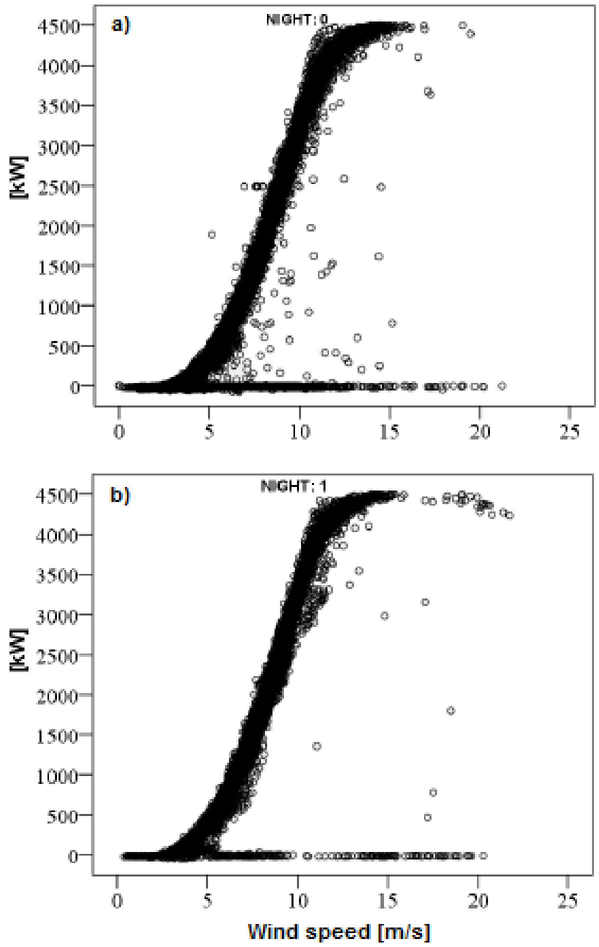

Figure 3. The electric power production of the nearest WT in respect of wind speed at the height of 140 m during a) day time 07-22h, and b) night time 22-07h.

The A-weighted equivalent SPL in respect of the electric power production of the nearest WT is presented in Figure 4. Background noise affected repeatedly the measured levels, especially, at day time when the electric power production was below 1000 kW. Therefore, we decided to focus on the measured samples during night time when the electric power production was at least 1000 kW.

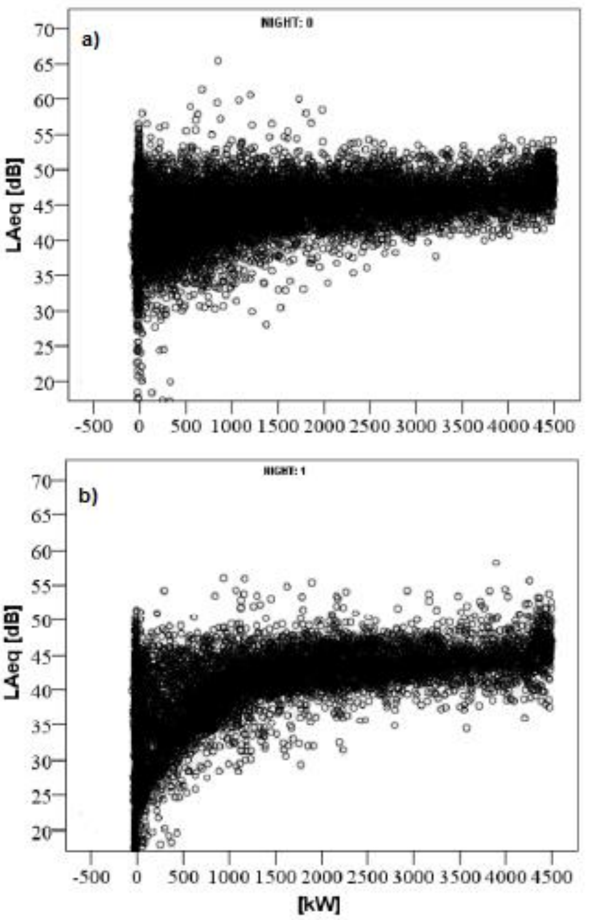

Figure 4. The A-weighted equivalent SPL, $L_{A,eq,10min}$, in respect of the electric power production [kW] of the nearest WT during a) day time 07-22h, and b) night time 22-07h. The results fulfilled the condition I (N=21211).

The effect of exclusion criteria II and III is presented in Figure 5.

The summary of the $L_{A,eq}$ results in various power ranges and during different exclusion criteria is presented in Table I.

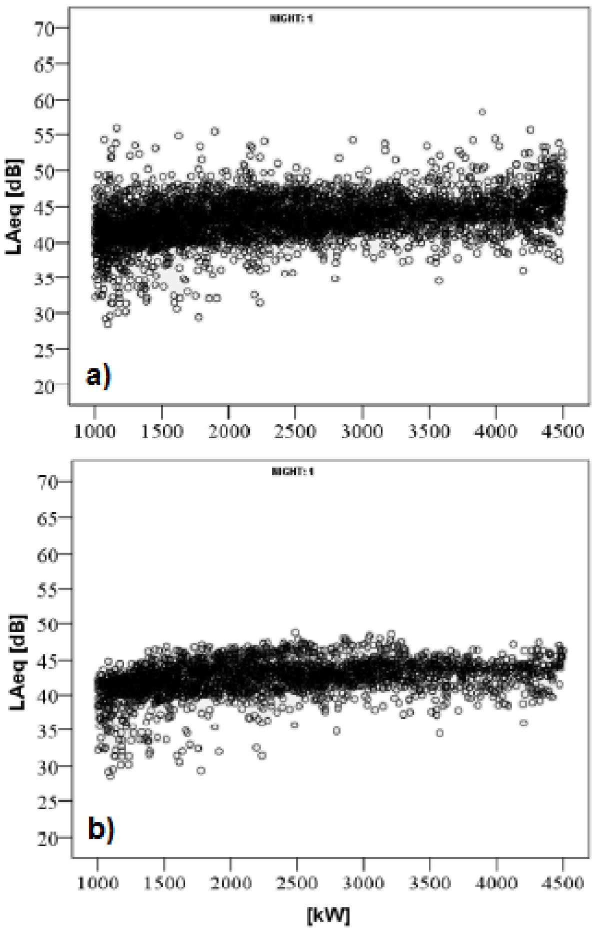

Figure 5. The A-weighted SPL, $L_{A,eq,10min}$, at night time in respect of the electric power production of the nearest WT when the samples were reduced according to a) condition I, b) conditions I & II & III.

Table I. Mean and standard deviation of $L_{A,eq}$ for different combinations of applied exclusion criteria and electric power ranges. N is the number of 10-min periods. The maximum power was 4500 kW.

Exclusion Criteria Power Production		N	$L_{A,eq}$ mean	$L_{A,eq}$ standard deviation
I	day	13233	44.1	4.1
P > 0 kW	night	7978	40.2	6.4
I	day	847	47.7	2.4
P > 4000 kW	night	538	45.4	2.9
I & II	day	80	44.7	1.6
P > 4000 kW	night	222	43.4	2.1
I & III	day	62	44.8	2.0
P > 4000 kW	night	283	44.2	2.3
I & II & III	day	34	43.8	1.2
P > 4000 kW	night	186	43.3	2.0

4. Discussion

The focus of discussion is on the night time data, because the background noise was lower. The mean $L_{A,eq}$ of the whole 5 month measurement period was 40.2 dB at night time. However, the standard deviation was large and power criteria and exclusion criteria were applied to determine the $L_{A,eq}$ during maximum power output.

The mean night time A-weighted SPL, $L_{A,eq}$, was 45.4 dB and the standard deviation was 2.9 dB when the nearest WT produced electric power over 4000 kW. The mean $L_{A,eq}$ was 43.3 dB after the exclusion criteria II & III. Correspondingly, the standard deviation decreased to about 2 dB (standard error of the mean 0.15 dB). This result is in agreement with the short term measurement result $L_{A,eq}$=44 dB [2] and the predicted value $L_{A,eq}$=44 dB [3].

The mean $L_{A,eq}$ results (Table I) do not include background noise correction, because controlled reference measurements were not made while the WTs were stopped. Therefore, the results that passed both exclusion criteria II & III provide an estimate of the maximum equivalent A-weighted SPL produced by the WTs on the measurement site. The uncertainty of our result is still assumed to be ±2 dB during the night when all three exclusion criteria were applied.

5. Conclusions

The long-term measurement results were in agreement both with the predicted $L_{A,eq}$ and with the measured $L_{A,eq}$ obtained by a short-term measurement in the same yard by an independent consulting company. The findings give no reason to doubt the validity of short-term immission measurements according to [1] in this yard. However, further long-term measurements are needed to validate our findings.

Acknowledgement

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References

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