Low-frequency noise incl. infrasound from wind turbines and other sources

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ABSTRACT

In recent years, the issue of low-frequency noise – especially infrasound – has aroused great interest not only among experts, but also among the general public. The reason for this is probably the discussion about the expansion of wind power. In the years 2013-15, LUBW Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg and company Wölfel Engineering performed extensive measurements of low-frequency noise (incl. infrasound of 1 Hz and higher) in the immediate vicinity of six wind turbines, in urban and rural areas as well as in areas that are explicitly dominated by road traffic. The aim of the project was to collect comparable data about the occurrence of infrasound and low-frequency noise in the vicinity of wind turbines and other sources. The measurements on wind turbines with a capacity of 1.8 to 3.2 MW were performed simultaneously with different distances to the respective wind turbine. The infrasound emitted by wind turbines could be measured very well in the close vicinity of the turbines. Here, the sound intensity is below the human perception threshold. The large amount of data was documented in different evaluations (e.g. linear third-octave band levels, narrow-band spectra, G-rated overall sound pressure levels depending on wind speed or time of day). The measurement method and the main results are presented in this paper.

Keywords: Infrasound, Wind turbine, Measurement, Low-frequency noise

(See . http://www4.lubw.baden-wuerttemberg.de/servlet/is/257896/?shop=true&shopView=6647 .)

1. INTRODUCTION

In the years 2013-2015, the State Institute for Environment, Measurements and Nature Conservation (LUBW) and company Wölfel Engineering performed extensive measurements of low-frequency noise (incl. infrasound of 1 Hz and higher) in the immediate vicinity of six wind turbines. Furthermore, measurements were performed in urban and rural areas (without source reference) as well as in areas dominated by road traffic and measurements on technical equipment in residential buildings. The aim was to collect current comparable data about the occurrence of infrasound and low-frequency noise of wind turbines and other sources.

2. METHODS

Various criteria had to be taken into consideration when selecting the measuring locations. For example, roads with heavy traffic, forests and industrial plants had to be strictly avoided. Different types of wind turbines (WT) were selected with a capacity between 1.8 and 3.2 MW. Parallel and synchronous measurements were performed at three measuring points each, at different distances to the respective WT. The nearest measuring point was determined in accordance with FGW guideline and IEC 61400-11 depending on hub height and rotor diameter. If possible, the more distant measuring points were positioned at distances of about 300 m and 700 m with identical set-up. To record the low frequencies, measuring

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microphones (G.R.A.S.) calibrated to measure low frequencies were used with a lower limit frequency of approx. 1 Hz. The microphones were mounted on sound-reflecting plates and provided with double windscreens. Placement of the measuring microphone in a hole in the ground in relevant measuring situations did not lead to additional level reductions of the wind-induced background noise in the infrasound range. When measurements on a WT were performed, possible neighboring turbines were stopped. All measuring points were evaluated by analogy to the FGW guideline and IEC 61400-11 (1). In addition, G-levels and narrow-band spectra were determined from the recorded audio files subsequent to the measurements.

3. MEASUREMENT RESULTS

3.1 Wind Turbines

In total, measurements on six wind turbines were carried out (Enercon E-66, E-82 and E-101, REpower MM92 and 3.2M114 as well as Nordex N117). As an example, the results of the measurement on a 2.4 MW Nordex N117 will be presented in the following. The results for the other turbines are basically comparable and described in detail in the project report (2)

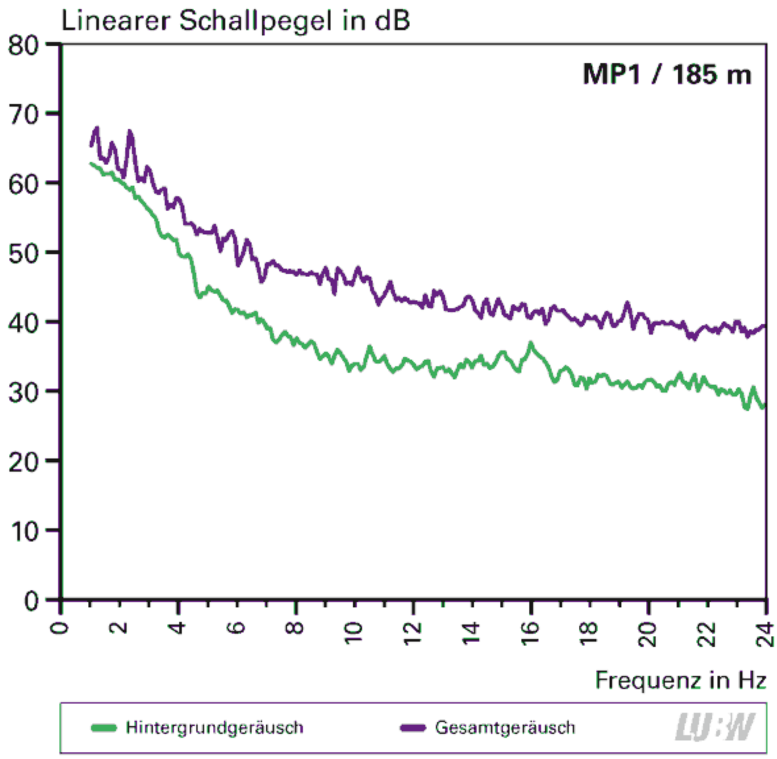

Figure 1 - Narrow-band spectrum (resolution 0.1 Hz). Total noise (violet, upper curve) with WT in operation and background noise (green, lower curve) with WT out of operation, measured in near sound field at a distance of 185 m to the turbine. The discrete frequencies below 6 Hz are easily visible (upper curve).

Figure 1 shows the narrow-band spectrum from 1 to 24 Hz with a resolution of 0.1 Hz, which was measured at the reference point at a distance of 185 to the turbine. In the period of time chosen for this representation, the average measured wind speed in the operating noise was approx. 7.6 m/s, in the background noise approx. 6.9 m/s. If possible, periods with similar wind speed and little gustiness were selected for the evaluation. In the ordinate, the measured linear sound pressure level without frequency weighting is shown. With the WT in operation, discrete maxima in the frequency range below 6 Hz are clearly visible. They correspond to multiples of the rotor passage frequency (here visible at approx. 0.6 Hz: 1.2 Hz, 1.7 Hz, 2.3 Hz, 2.9 Hz, etc.) For the far field (Figure 2), there is hardly any difference noticeable between operating noise and background noise. The discrete maxima that are clearly visible in the near field do no longer exist.

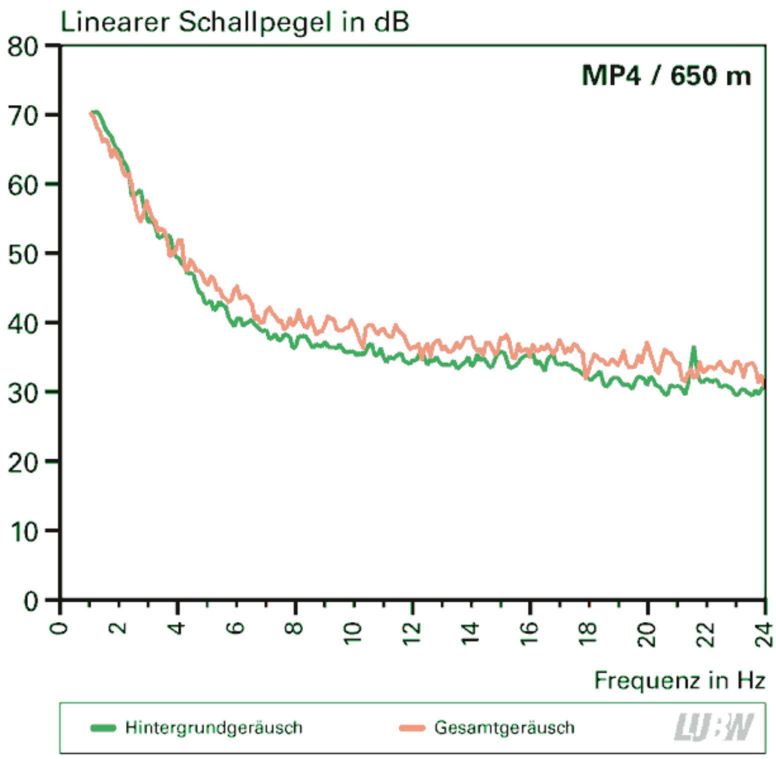

Figure 2 - 0.1-Hz narrow-band spectrum of total noise (orange, upper curve – with WT in operation) and background noise (green, lower curve – with WT out of operation) measured at a distance of 650 m.

Figure 3 (upper diagram) shows the measured average A-weighted and G-weighted overall sound pressure levels (according to ISO 7196) for the entire measuring period, at a distance of 185 m to the plant. Each data point corresponds to a 10 s equivalent continuous sound pressure level. The levels are plotted against the corresponding wind speeds (at a height of 10 m and rounded to 0.1 m/s). Measurement times with disturbing noise were excluded from the analysis. The G-levels are shown red and green respectively - red with the turbine in operation (total noise), green with the WT out of operation (background noise). The level difference between operating and background noise in the G-weighting is clearly visible. The A-levels of operating noise are additionally specified (violet). At a distance of 650 m (Figure 3, lower diagram) no significant differences between operating and background noise are visible any more in the G-weighting. The broader distribution of measured values in the A-level can be explained by the stronger influence of the background noise.

In Figure 4, the measured sound pressure levels of a representative period of time for the operating noise at the three measurement points at different distances are compared as linear third-octave levels. For each measurement, a period of time was chosen in which the wind speed was as constant as possible. Here the average measured wind speed was 7 m/s.

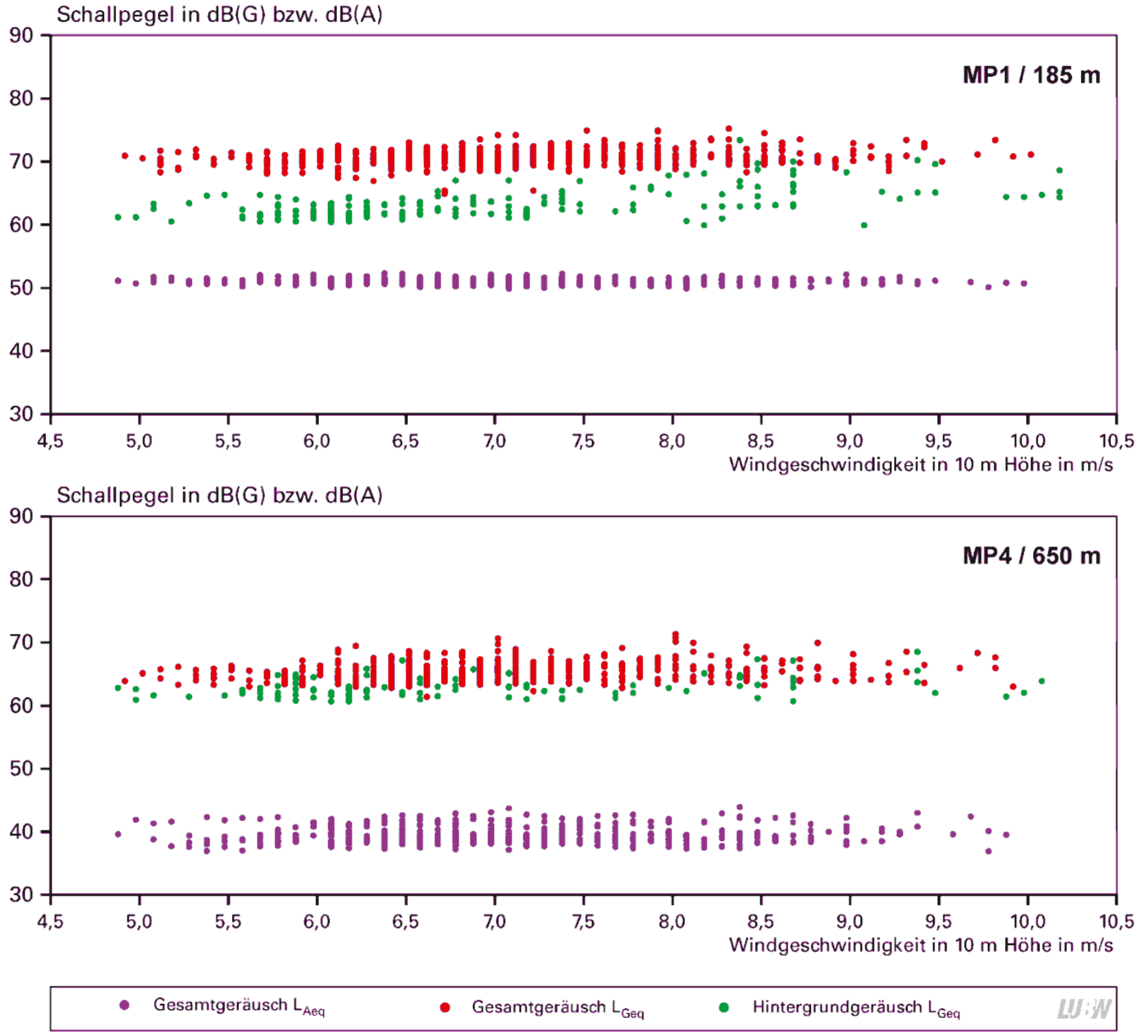

Figure 3 - A-level (violet dots) and G-level (red dots with WT in operation, green dots with WT out of operation). At a distance of 185 m (upper diagram), significant differences in the G-level between WT in and out of operation can be seen. At a distance of 650 m, there are only minor differences (lower diagram).

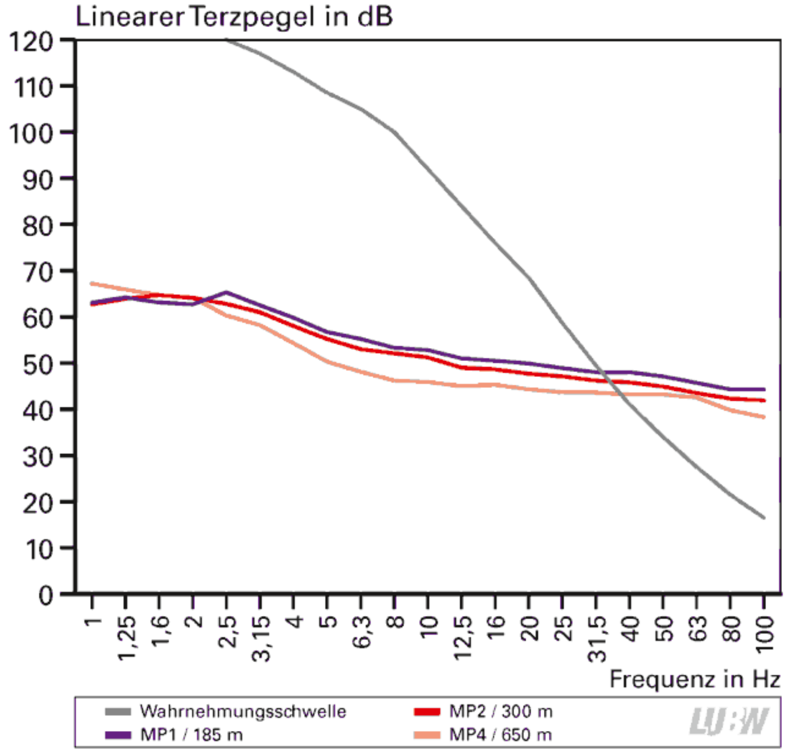

Figure 4: Third-octave band spectra of the total noise measured at distances of 185 m, 300 m and 650 m to the WT. For comparison purposes, the perception threshold was additionally included in the figure (grey).

In addition, the perception threshold was shown according to the draft of DIN 45680:2013 (3). Below 8 Hz, it was supplemented by literature values (4). In the figures, the background noise, as it is e.g. generated by surrounding vegetation at these wind speeds, for example, is included in the measured total noise. From about 32 Hz upwards, the levels are below the perception threshold for all measuring points. In case of infrasound, they are even very far below the perception threshold, by 20 up to more than 50 dB below the threshold. Comparable results were found in the other measurements that were carried out. At distances of 120 m to 190 m, the G-levels were between 60 and 80 dB(G) in all turbines, incl. wind noise. According to a Polish study, values of about 89 dB(G) were measured in the center of a wind farm with 25 Vestas V80 turbines. At the edge of the wind farm, about 67 dB(G) were measured (5).

3.2 Road traffic

During the project, intensive measurements of road traffic noise also have been performed, both outside and inside buildings. Figure 5 shows linear third-octave band spectra (hour average sound pressure level) throughout the total frequency spectrum, measured on the immission side at an inner-city street in the afternoon between 16:00 and 17:00. Between 0:00 and 1:00, they are 10-15 dB lower. The resonance in the low-frequency range, here with a maximum of about 40 Hz, is striking.

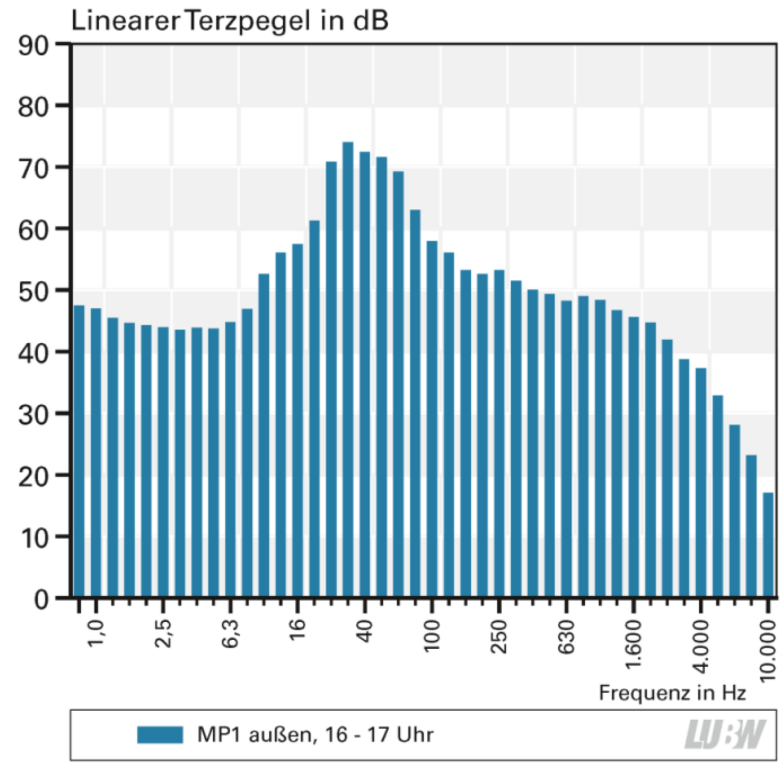

Figure 5: Third-octave band spectrum road traffic (immission), recorded on weekdays between 16:00 and 17:00. The traffic intensity is 14,000 vehicles/24h with a percentage of trucks of 3 %.

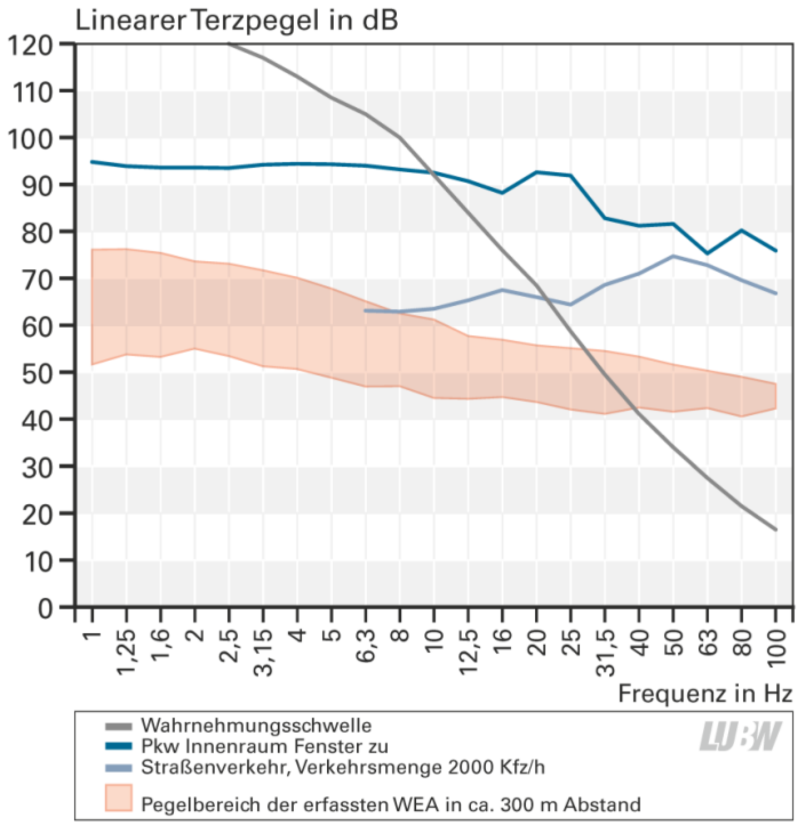

Figure 6: Third-octave band spectrum road traffic at the permanent measuring station Reutlingen (blue curve center) with 2,000 vehicles/h. Results of the WT measurements (red) and level inside a running passenger car with closed windows (upper blue curve). Perception threshold (grey).

Further data were recorded by the permanent measuring station Reutlingen, Baden-Württemberg (6) and are shown in Figure 6. For comparison purposes, the results of the wind turbine measurements were added, as well as the levels measured inside a running passenger car (130 km/h, with closed windows). The latter are significantly higher.

3.3 Urban and rural Background

The measurements in the urban background without source reference were performed on a rather quiet square without direct influence of traffic noise. They could be performed with no or low wind. As expected, the levels fall respectively, from day all through the evening until night (Figure 7).

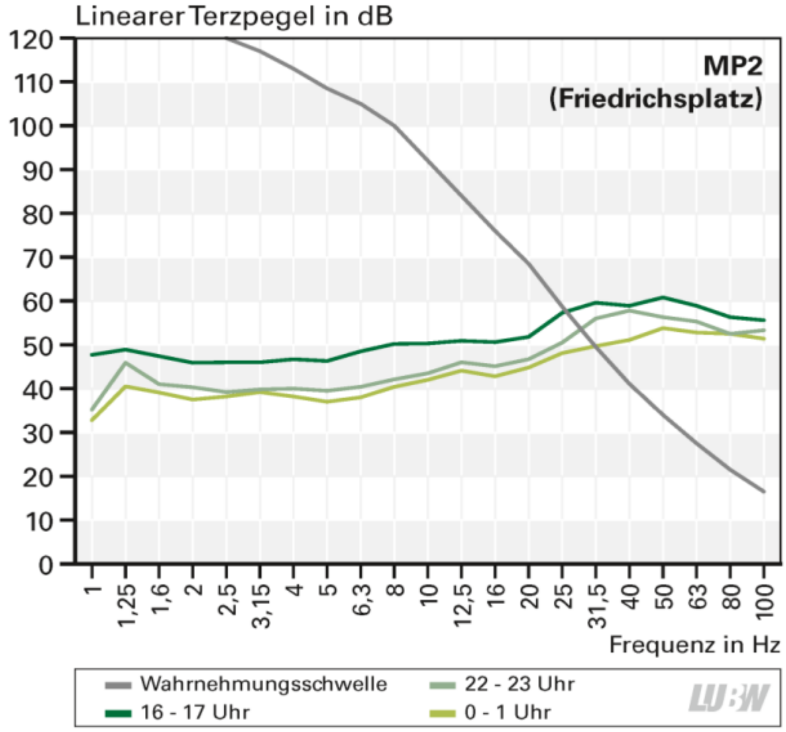

Figure 7: Third-octave band spectra (green) inner city of Karlsruhe on a rather quiet square at different times. Perception threshold (grey).

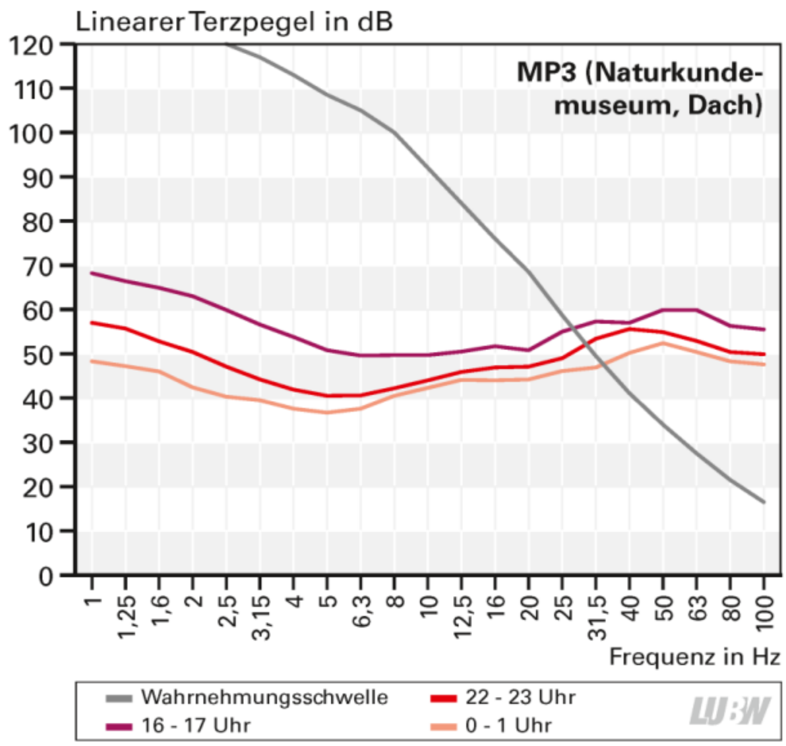

Figure 8: Linear third-octave band spectrum inner city of Karlsruhe, measured on a roof at different times. Perception threshold (grey).

The values in the infrasound range measured on the roof of an adjacent building tend to be higher than those measured at the square, which might be associated with interferences from more distant sources (Figure 8).

The measurements in the rural background were performed without wind turbines around. Figure 9 shows the results in a meadow, in the free field, with values measured at wind speeds of 5 resp. 10 m/s. They are in a similar range as for measurements in the immediate vicinity of WT. The levels measured at the edge of the forest and in the forest were lower.

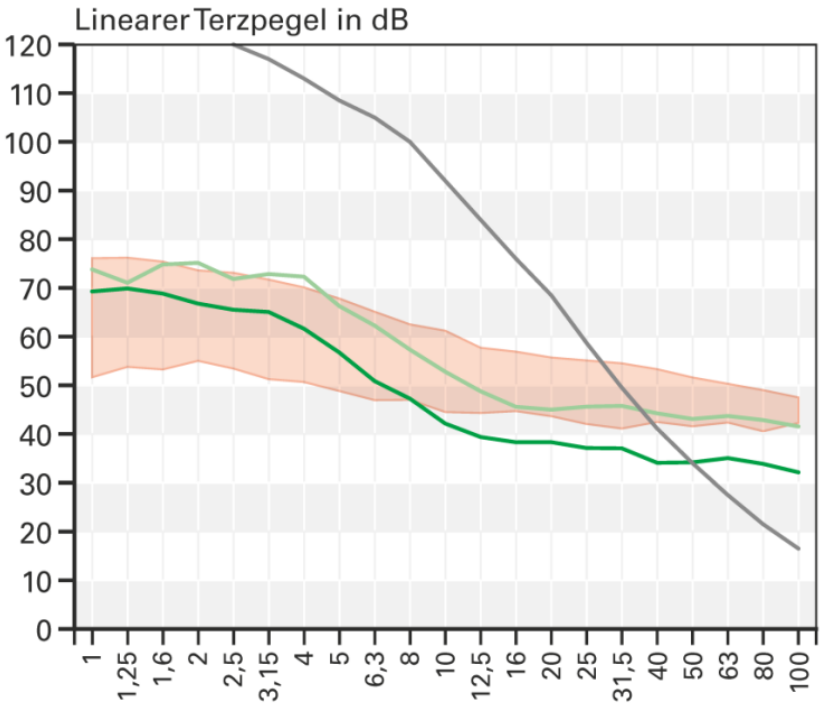

Figure 9: Comparison of the noise situation in the free field (green – without WT in the vicinity) with the level range of a WT at a distance of 300 m (red). Perception threshold (grey).

3.4 Sound sources in the household

As regards the sound sources in the household, oil-fired heating and washing machine are noticeable sound sources in the low-frequency range (Figure 10). Both of them contain significantly low-frequency portions (oil burner, spinning) during operation, whereas the gas-fired heating works relatively quiet.

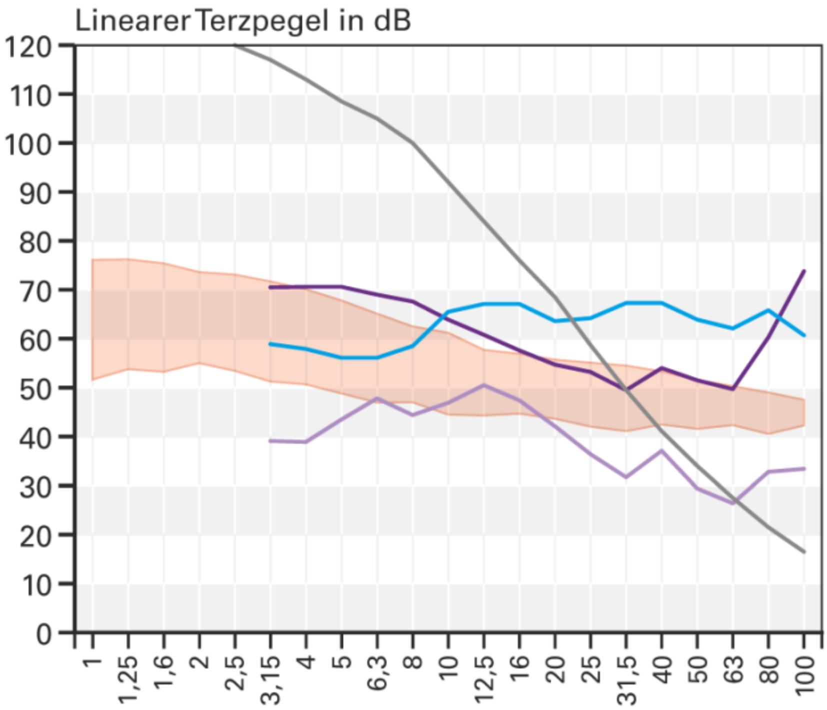

Figure 10: Third-octave band spectra of oil-fired heating (violet), washing machine (blue) and gas-fired heating (lowest curve). For comparison WT (red), perception threshold (grey).

4. CONCLUSIONS

Infrasound is produced by a large number of different technical and natural sources. It is an ordinary part of our environment that is present everywhere.

The contribution of wind turbines, however, is insignificant. The infrasound level produced by wind turbines is significantly below the human perception threshold. In our investigations in the vicinity of the plants, the levels could well be measured, the natural frequencies below approx. 6 to 8 Hz could also be determined. At the more distant measuring points, however, they could not be detected any more. The differences between wind turbines in and out of operation were negligible or non-existent.

There is no scientifically substantiated evidence of adverse health effects of infrasound in this level range.

The comprehensive project report which provides much more information and data is readily available on the Internet (2).

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