WIND TURBINE NOISE - DOSE-RESPONSE RELATIONSHIP

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Introduction Operating wind turbines are a new source of community noise and only few studies have evaluated their impact on people living nearby. An extensive dose-response study was performed in Denmark, the Netherlands and Germany 1993 [1]. They found only a weak correlation between A-weighted sound level and noise annoyance caused by wind turbines. The Danish part of the study was extended and a number of objective and subjective variables were added [2]. Of the objective variables, visual angle (the angle in degrees measured from the respondents dwelling to the hub with the ground as the horizontal line) explained the largest variance of noise annoyance in addition to sound level. Subjective variables of importance were whether the turbine noise could be perceived or not, perception of shadows and flicker and the attitude to the turbines' impact on the landscape. However, these studies were carried out at a time when the turbines still were rather small and none of the turbines in the Danish part of the study exceeded 155kW. As the size of the turbines has increased as well as the numbers erected, a need for further studies has been called upon. The aims of the study presented here were to evaluate the prevalence of noise annoyance from wind turbines and to study dose-response relationships between noise annoyance and calculated dBA levels. The intention was also to look at interrelationships between noise annoyance, visual disturbance and subjective variables.

Methods The investigation was a cross-sectional study comprising respondents exposed to different sound levels from wind turbines, performed in the south of Sweden in the summer 2000. The study areas comprised 16 wind turbines of which 14 had the power of 600 kW. Subjective responses were obtained through a questionnaire, which purpose was masked. Among questions of living conditions in the countryside, were questions directly related to wind turbines. Annoyance perceived outdoors was rated on five categories verbal scales ranging from "do not notice" to "very annoyed". A total of 356 respondents were included (response rate 69%). For each respondent outdoor sound level (dBA free field) from the nearest wind turbine were calculated based on wind conditions of 8 m/s with the wind direction towards the respondent according to [3]. Comparisons were made of the extent of annoyance between respondents living at different sound levels.

Results The proportion of respondents that noticed sound from wind turbines outdoors increased with increasing sound levels (Figure 1). At sound levels exceeding 35.0 dBA, 85% or more reported that they could hear the sound. The proportions of outdoor annoyance (rather and very annoyed) due to noise from wind turbines also increased with increasing sound level at sound levels exceeding 35.0 dBA. The correlation between noise annoyance from wind turbines and sound level was statistically significant (r_s=0.40; n=341; $p<0.001$). No respondent stated them selves rather annoyed or very annoyed at sound levels below 32.5 dBA. At the sound levels of 37.5-40.0 dBA the proportion very annoyed was 20% (n=8; 95%CI: 8-32%) and above 40 dBA it was 36% (n=9; 95%CI: 17-55%).
Visual causes of annoyance from wind turbines were all statistically significantly correlated to noise annoyance: shadows (r_s=0.49; n=339; $p<0.001$), reflections (r_s=0.43; n=335; $p<0.001$) and changed view (r_s=0.47; n=340; $p<0.001$).

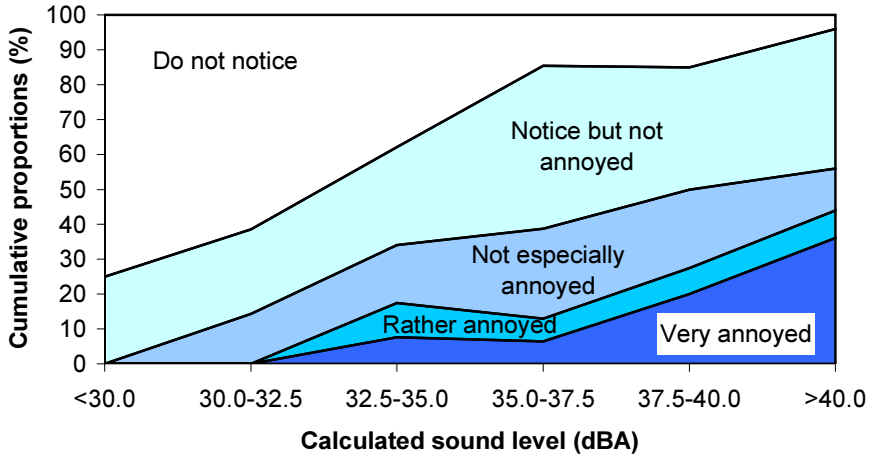

Figure 1 *The cumulative proportions of perception and annoyance outdoor from wind turbines at different intervals of noise exposure from wind turbines.*

To explore the influence of the subjective variables on noise annoyance, binary multiple logistic regression was used. In the first model only noise exposure was used as independent variable. The Exp(B) was 1.87, i.e. the odds for being annoyed by noise from wind turbines would increase 1.87 times (95%CI: 1.47-2.38) from one sound category to the next. When adding the subjective variable "attitude to the wind turbines visual impact on the landscape" as an independent variable, the influence of the noise exposure decreased, but was still statistically significant (Exp(B) =1.74; 95%CI: 1.29-2.34). The fitness of the model also increased. Adding the two remaining subjective variables "sensitivity to noise" and "general attitude to wind turbines" did not decrease the influence of noise exposure or increase the fitness any further.

Concluding comment A dose-response relationship was found, but as in previous field studies other variables than sound level influenced noise annoyance. The correlations between dose and response (0.40) found in this study correspond well with the results from other studies regarding community noise [4]. It is too early to create a dose-response graph for noise from wind turbines, as has been done with other sources of community noise [5]. A comparison shows however, that noise from wind turbines seem to be annoying at lower levels than for instance transportation noise. This could be due to the fact that wind turbines have a large visual impact on the landscape and that the rotor blades are moving. In this study it was mainly visual variables that influenced noise annoyance. The high proportions of noise annoyance could also be due to the special character of the sound. At a distance, the sounds from the rotor blades dominate. This sound has a swishing character and a modulation frequency of around 1.3 Hz and can thus be hypothesised to be easily perceived and also annoying.

Keywords: wind turbine, noise annoyance, visual impact

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