Influence of weather conditions on immision levels near an outdoor shooting range

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Introduction

Outdoor shooting activities, such as clay pigeon shooting (shooting at clay targets with a shotgun), are an important source of noise pollution. To deal with the annoyance in the neighbourhood, civil shooting facilities are subject to regulations limiting the acoustic load in the environment.

A common way to assess shooting noise is described in the ISO 1996 standard [1, 2] defining measurement and assessment procedures of environmental. The rating level depending on both the immission levels and the number of shots per evaluation period T_n, noise standards can be met by controlling this number.

However, immission points being at several hundred meters, sound propagation is significantly affected by meteorological conditions. Moreover, firearms don't radiate their acoustic energy in a symmetrical way. All places in the surrounding are thus not affected by noise in the same way.

This paper presents the results of an experimental study of the combined effects of weather conditions and location on noise levels near an outdoor shooting club.

Measurement campaigns

Experimental data were collected around a shooting center near the city of Mons in Belgium. It lies in a lowland and agricultural region and has nearly 700 registered shooters. The shooting noise being audible at a great distance, it has an impact on a significant number of residents despite the club is located in a rural area.

Although different shooting activities are proposed, clay pigeon shooting, practiced outdoors, is the most troublesome, the others taking place in inner tunnels.

Shooters take place in 5 shelters whose walls are covered with acoustically absorbent materials. To limit the noise propagation as many as possible, shelters are surrounded by earth banks. Moreover, an earth mound of about 10 m high is situated at +/- 100 m in front of shooters. Figure 1 shows the general disposition of the facilities.

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Figure 1: Aerial view of the clay pigeon shooting facilities

Four measurement campaigns were conducted at various locations (Figure 2). $L_{Aeq,T}$ with integration period of 50 ms were recorded using class 1 sound level meters. The exposure levels of the shots detected were derived from these data. In addition, a weather station was placed in an open area near the shooting ranges. The wind velocity was recorded every 2 s.

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Figure 2: Measurement positions

Table 1 summaries the measurement conditions. Noise levels were also recorded at position 1 (on the mound) to ensure that noise source levels were similar. Position 2 is at approximately 800 m from the shooters.

Table 1: Measurement conditions

Dataset	Positions	Number of shots	Duration	Mean wind direction	Mean wind speed
1	1 and 2	1451	1h25	ENE	1.5 m/s
2	2 (fixed)	1772	2h12	SE	1.9 m/s
	3 to 6 (mobile)	130-500	15-30 min.		
3	1 and 2	1747	1h30	WSW	2.7 m/s
	6	164	15 min.		
4	1 and 2	1835	2h30	NNE	2.4 m/s

Influence of wind direction

During each measurement campaign, the noise level was measured at position 2. This location is close to the residents frequently complaining of noise and is used by the authorities to check the compliance with noise limits. At this place, the energetic mean of the exposure levels (L_{AE}) of the detonations perceived show variations up to 19 dBA (Table 2).

Table 2: Energetic mean of L_{AE} of the perceived detonations at position 2

	Dataset 1	Dataset 2	Dataset 3	Dataset 4
Mean L_{AE} (dBA)	56	64	45	46

The analysis of the wind conditions explains these variations. We can see on Figure 3 that the particularly high level of dataset 2 corresponds to downwind conditions. Conditions were slightly downwind in dataset 1 and slightly headwind during the two last measurement campaigns.

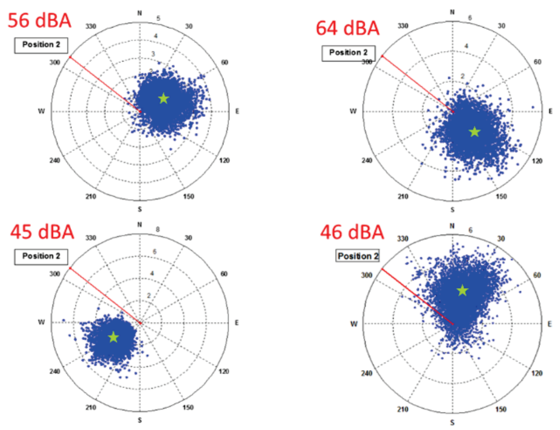

Figure 3: Wind conditions and mean L_{AE} (red lines correspond to source-receiver direction, blue points to the instantaneous wind velocities and green stars to their mean values)

These findings can be even better highlighted by plotting the mean L_{AE} as a function of the mean wind direction component in the receiver direction (Figure 4). At position 2, the correlation between these variables is almost 1. It can be concluded that the variations of the exposure levels at position 2 are mainly due to the wind direction since the wind speeds were similar.

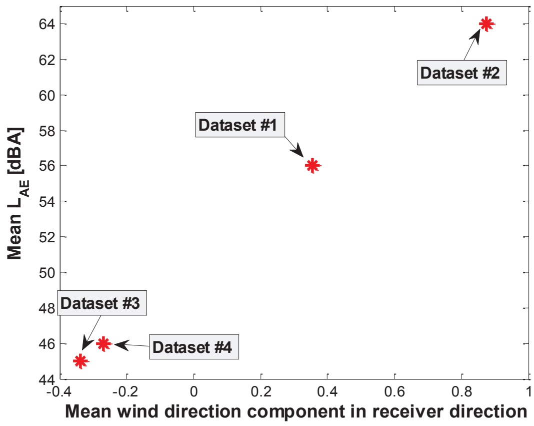

Figure 4: Correlation between the mean L_{AE} and the mean wind direction component in the receiver direction at position 2

Spatial distribution of noise in the environment

During the second measurement campaign (dataset 2), two sound level meters were used simultaneously. One was placed at position 2 and stayed there throughout the measuring time. Measurements were also carried out around the shooting club with the other sound level meter (positions 3 to 6). Figure 5 shows the mean exposure level of the detonations perceived at the different locations together with the wind conditions.

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Figure 5: Mean exposure level of perceived detonations at different locations (Dataset 2)

In this case, the wind was nearly blowing in the direction of position 2 and position 5 was in an acoustical shadow zone. The huge difference between the exposure levels found at these two locations is also explained by their position relative to the firing line. Given the directivity of firearms, most of the acoustic energy is sent in the shooting direction. Combined effects of wind direction and directivity explain thus the particular high level measured at position 2. *A contrario*, a smaller proportion of the acoustic energy is sent in towards position 5, especially as the sides and back of the sheds send back a part to the front.

During the third campaign (dataset 3), one sound level meter was used successively at different places. It stayed approximately 1 h 30 at position 2 and 15 minutes at position 6. Wind was blowing from WSW. Figure 6 shows that the mean exposure level was lower at position 2 than at position 6. However, because of the source directivity and the effects of the shelters and earth banks, L_{AE} at position 6 is much lower than that observed at position 2 in dataset 2 despite downwind conditions in both cases.

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Figure 6: Mean exposure level of perceived detonations at different locations (Dataset 3)

Shooting noise assessment in Belgium

Belgium being a federal state, noise issues are handled by the regions. Shooting noise provisions are defined in sectoral conditions both in Flanders and Wallonia. They are based on the same formula derived from the ISO 1996 standard [1]. The rating level (1) corresponds to an hourly equivalent level plus an adjustment for high impulsive noise. Isolated shots are described by their sound exposure level.

$$L_{Ar,1h} = 10\log\left(\frac{1}{3600}\sum_{i=1}^{n} 10^{0.1\,L_{AE,i}}\right) + 13 \quad [\mathrm{dBA}] \quad (1)$$

Sectorial conditions differ in terms of limits and application. In Wallonia, all new installations are concerned by the noise provisions while particular conditions still regulate existing facilities. The rating level and the limit applying to the shooting center considered in this study is given by equation (2), with n standing for the number of shots detected during the past hour.

$$L_{Ar,1h} = 10\log\sum_{i=1}^{n} 10^{0.1 L_{AI,max,i}} - 33 < 45 \quad [\mathrm{dBA}] \quad (2)$$

In Flanders, noise provisions apply to all shooting ranges except in the case of clay pigeon shooting and traditional rifle shooting.

Impact of weather conditions on noise management

As $L_{AI,max}$ were also recorded during the measurement campaigns, the largest numbers of shots per hour allowed to stay in the noise limits were derived from the four experimental datasets at position 2 and the current regulation.

In the context of an operating license renewal, the sectoral conditions could be applied with a limit of 50 dBA or 55 dBA. The largest numbers of shots corresponding to these noise provisions were also derived.

From Figure 7, it can be concluded that if position 2 is in downwind, or slightly downwind, position noise limits are very quickly exceeded whatever the rating level formula. By contrast, when wind conditions are less favourable to noise propagation the numbers of shots given by the sectoral conditions correspond to good operating conditions. However, the current regulation leads however to too few shots per hour.

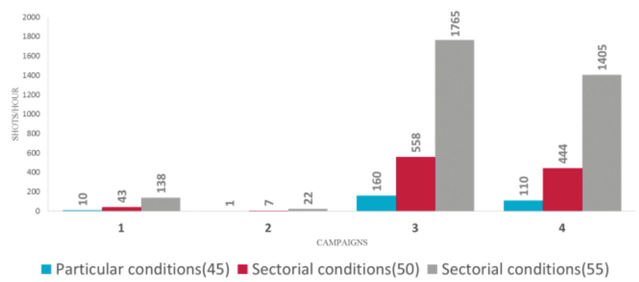

Figure 7: Number of shots per hour allowed to stay in the noise limits depending on weather conditions

If these findings are extrapolated by only considering the wind direction, it can be concluded that when wind is blowing from the directions in red on Figure 8, shooting activities could not be compliant with the noise regulation. The statistical wind direction distribution shows that this situation occurs half the time. The rest of the time, no significant noise problem should be expected.

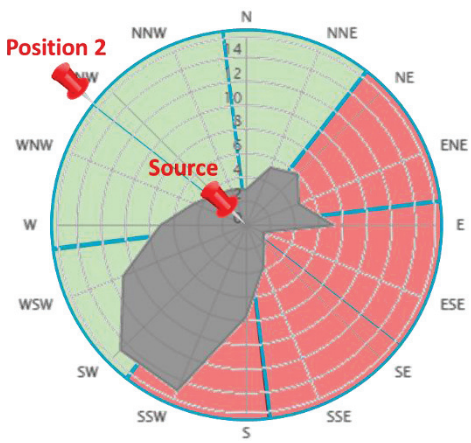

Figure 8: Yearly wind direction distribution in % (source:www.windfinder.com)

Conclusions

During the measurement campaigns carried out around a shooting facility, a large variability in levels measured at the same place was noticed. In addition, simultaneous measurements at different locations around the club (at similar distances) showed that noise could even be inaudible in some places. Considering wind speeds were similar, a strong correlation between the wind direction component in the receiver direction and the mean shooting noise exposure level was found at the location most exposed to noise.

Comparing the experimental data and noise regulations leads to completely opposite situations depending on the weather conditions. These results show that the current regulation based on the worst case isn't suitable for clay pigeon shooting. To combine profitability of the shooting facilities with the respect of noise standards, long-term noise levels should be considered to take into account the weather conditions.

References

1. ISO 1996-1: Acoustics - description, measurement and assessment of environmental noise - part 1 : Basic quantities and assessment procedures, 2003.

2. ISO1996-2: Acoustics - description, measurement and assessment of environmental noise - part 2 : Determination of environmental noise levels, 2007.