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Noise emission from grain dryers and potential noise pollution

M. Reinvee*, M. Luik and P. Kliimak

Institute of Technology, Estonian University of Life Sciences, Kreutzwaldi 56, EE51014 Tartu, Estonia; *Correspondence: mart.reinvee@emu.ee

Abstract. Noise is known as an irritant both in industrial and living space settings. Also the negative effect of noise on people's health and wellbeing is widely recognised. Usually in the work environment the impact of noise can be easily reduced, for example, by providing personal protective equipment or using the appropriate administrative tools. However, in residential areas near by to industry, the problem is quite different. Although the population density in Estonia is quite low compared to other European countries, there are rural areas where industrial noise sources are located nearby to people's homes.
Also the awareness of noise hazard is rising among people, and company owners are forced to diminish the noise levels of production. This generates a need for knowledge about noise reduction. Current study aims to compile data about the noise emission of grain dryers with main concern towards noise direction. Results of the study can be applied in developing layouts of grain dryers or in noise barrier development.
Noise levels around the perimeters of different type grain dryers were measured with a TES-1358A sound analyser in 1/3 octave band segregation. Measurement data was compiled into noise maps. Specifications of Estonian laws were taken into account.

Key words: grain dryer noise, noise emission, non-occupational noise.

INTRODUCTION

With agricultural production noise pollution is clearly a concurrent problem. Production without machinery is unthinkable, therefore attention must be paid to noise reduction. Currently most scientific research on agricultural production deals with crop cultivation and the main concern seems to be either tillage or harvest operations. Meanwhile comparison of the results of recent studies dealing with machinery characteristics (Dewangen, 2005; Sümera et al., 2006; Aybek et al., 2010; Bliski, 2013) and rural area population's hearing exposures (Humann et al., 2011; Humann et al., 2012;) does not justify the focus solely on the operation of machinery. A conclusion may be drawn that machinery operators are exposed to noise levels that are not significantly higher than the noise levels of other farm tasks.

Usually agricultural production is associated with rather remote areas where no living spaces are nearby. Although it may be true in the case of crop cultivation, it may not be so with first processing as the need for workforce and infrastructure dictates the location of buildings. While the population density in Estonia is quite low, there are still numerous blocks of flats in rural areas. Thus living spaces concentrated in such ways may be unfavourably exposed to noise caused by first processing buildings.

Due to developments in public health and increased awareness about civil rights and the effects of noise on human health, agricultural production companies must face the noise problem in order to avoid compulsory legal enforcement and maintain good community relations between them and nearby inhabitants, which are reported to be equally important. The aim of the study was to compile data about grain dryer noise emissions in order to assess its significance in non-occupational noise pollution.

MATERIALS AND METHODS

From August 16th to November 22th noise emissions of continuous flow type grain dryers (GD1, GD2, GD3, GD4) were measured. For this purpose IEC 60651 type 2 noise level meter TES-1358A with accuracy ± 1.5 dB was used. The goal of the measurements was to determine whether the layout of the grain dryer had any effect on noise emission. In order to achieve the goal, measurement data was compiled into noise maps for further analysis.

The capacities of grain dryers ranged from 21 to 29 t/h, meanwhile depending on the technology (whether two or four fans were needed) the installed fan power ranged from 22 to 78 kW.

Before the measurements the surroundings of all sites where analysed in order to determine measurement settings. After the consideration of various factors (terrain, vegetation, other buildings, traffic, etc.) the distance from grain dryer to measurement points was chosen as 25 m.

The distance was measured with laser rangefinder Bosh DLE50 and measurement points were marked on the map. However, due to structural differences (for example, grain silo placement) it was still impossible to cover all angles on the perimeter. Also, in order to eliminate the effect of building size a different number of measurement points were chosen per grain dryer. Where possible the caps between measurement points were filled with linear interpolation. When filling the caps the following criteria were used: 1) no more than two consecutive measurement points are missing; 2) equivalent sound pressure (SPL) level difference between two existing measurement points was less than 3 dB.

After analysing work cycles and varying the duration of measurement samples it became evident that the optimal sample time for equivalent SPL is between 1 to 5 min. As the noise is quite monotonous, sample time 1 min was chosen but the quality of measurements was evaluated on field. Quality of sample was assessed on the difference of minimal and maximal SPL. If the difference was >10 dB (human ear perceives it as twice as loud) the sample was rejected. Thus the effect of unforeseen factors such as barking dogs or passing cars was diminished.

To show the need to consider grain dryer placement the inverse distance law was used. Estonian law clearly states that the sound pressure level in living spaces must not exceed 55 dB during night time (Riigi Teataja, 2002).With equation 1 the distance where grain dryer's SPL is decreased to 55 dB was calculated.

$$r_2 = r_1 \cdot 10^{\frac{L_1 - L_2}{20}}, \quad (1)$$

where r_2 is distance where desired SPL (L_2) is met, m; r_1 – distance of measurement 25 m; L_1 – measured SPL at 25 m, dB; L_2 – desired SPL 55 dB.

Therefore calculated r_2 indicates the theoretical shortest distance from the grain dryer to the nearest home.

RESULTS AND DISCUSSION

The measurement data was compiled into noise maps (Fig. 1), measurement point P1 indicates the direction of the main fan. In the surrounding of GD1 (Fig. 1-A) there was no physical obstacle to prevent the measurements between P10 and P11. However, due to the dimensions of the building and decrement of the SPL the impact of other noise sources was detected in this direction and the biased results are not shown.

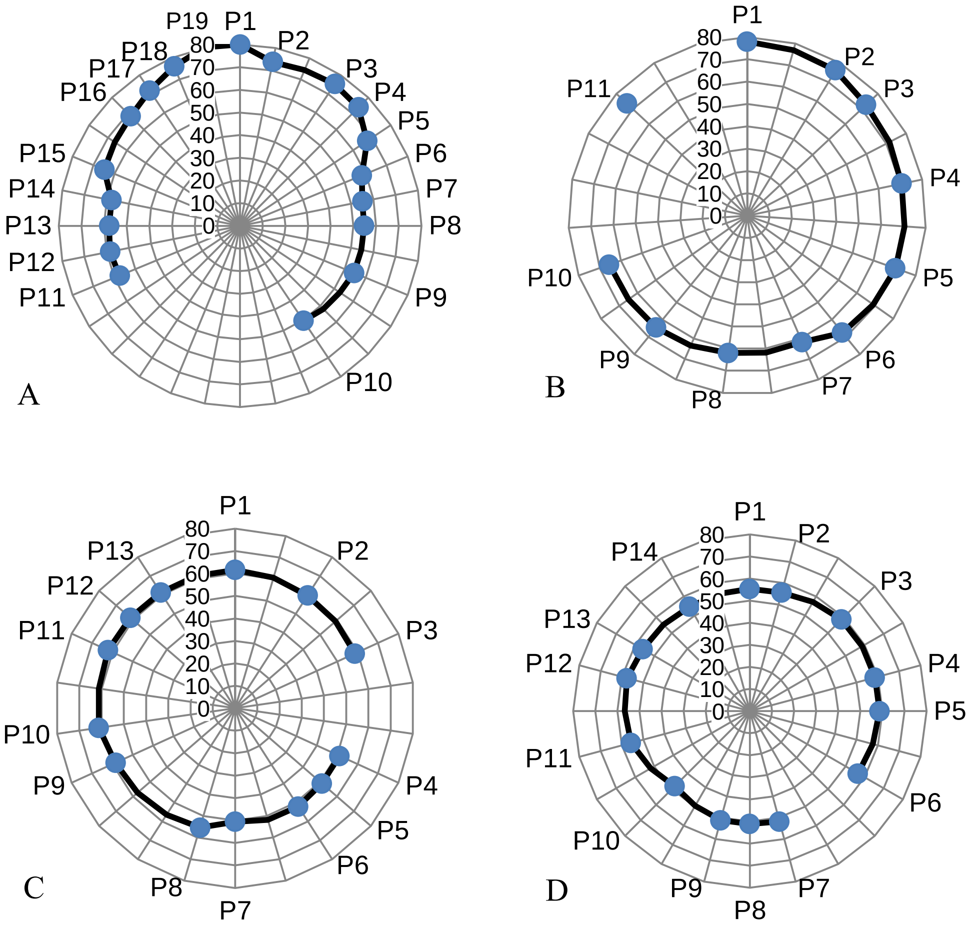

Figure 1. Grain dryers noise maps measured from 25 m around the perimeter of building, dB(A); A – GD1; B – GD2; C – GD3; D – GD4.

It should be obvious that P1 is the loudest measured point and the fans are the noisiest parts of the grain dryer. However, in case of GD3 and GD4 the highest SPL was measured in P11 and P5 which corresponds to the location of the crop dressing device. The shape of the noise emission graphic corresponds to the layout of the building. In case of squared layout, the noise emission seems to be more equal, i.e. the round shapes on the noise maps. In case of rectangular layout (Fig. 1-A), SPL difference between building sides are also easily distinguished by the human ear. Also, it's obvious that greater fan power (Fig. 1-A; Fig. 1-B) will result in greater SPL. However, the severity of the differences between GD1, GD2 and GD3, GD4 may have been increased by the direction of the air duct outlet. In case of GD1 and GD2 the air duct outlet was horizontal but GD3's and GD4's air duct outlets were directed to the sky so the directions differed by 90°. Main SPL differences are also indicated in Table 1.

Table 1. Measured Sound pressure levels, dB(A)

Parameter	GD1	GD2	GD3	GD4
Max	80.3	76.2	62.2	58.8
Quartile 3	74.2	72.3	61.3	57.4
Median	67.4	69.0	58.6	55.7
Quartile 1	57.8	64.8	52.0	52.5
Min	50.4	61.7	50.5	48.1

Based on equation 1 the shortest possible distance of the living spaces from the grain dryer was calculated. The results in Table 2 show the differences of grain dryers. Also, potential gain from careful layout planning is seen.

Table 2. Distance from grain dryer in metres where 55 dB criteria will be met

Parameter	GD1	GD2	GD3	GD4
Max	460	287	57	39
Quartile 3	228	182	52	33
Quartile 1	35	77	18	19

Results in Tables 1 and 2 differ because of the logarithmic nature of the dB scale. The effect of grain dryer misplacement does not emerge from the measurements of GD3 or GD4. Meanwhile, in case of GD1 proposing a layout where the living spaces are directed towards P1 (Fig. 1) would show the designers incompetence.

Before planning the grain dryer location, the surrounding area should also be investigated, as the nearby vegetation could be used to reduce noise. It has been pointed out that the tree belts which are higher than the receiver provide noise reduction from 3 to 10 dB depending on tree characteristics. Density, height, length and width of tree belts are the most effective factors in noise reduction. In fact, the belts should be more than 60 m long and 10 m wide to provide the greatest reduction. Leaf size and branching characteristics absorb noise. Moreover, shrubs are also effective in reducing noise owing to scattering from their dense foliage and branches. Therefore, shrubs should be planted under trees to enable the tree belts to provide the best reduction effect (Fang & Ling, 2002). Using trees as primary noise reduction involves a risk in overestimating the damping effect of tree belts, however, based on equation 1 the distance from the grain dryer to the living spaces could be reduced by up to three times.

Considering the grain dryer's layout is also economically important, it has been suggested that adding a muffler to the grain dryer increases the cost of the grain dryer by 2.5–3%, however, this will increase drying costs by around 1% (Kallas, 2006). Reducing transmission of sound waves by combining absorbent materials with barrier materials and installing them in tight-fitting enclosures around stationary sound sources is believed to be less costly. Using sound blanket panels hanging in front of the grain dryer has shown SPL reduction up to 10 dB (Fraser, 2012).

It is widely known that tonal noise (distinctive to engine noise) is significantly more disturbing than broadband noise. Thus the question how noise energy is distributed around the spectrum becomes particularly interesting. It is even stated by law that if the level in one 1/3rd octave band is ≥ 5 dB higher than the level in the two adjacent bands, then a clear audible tone is likely to be perceived and an additional 5 dB should be added to total measured SPL (Riigi Teataja, 2002).

SPL comparison of 1/3 octave bands indicated that not only SPL but also frequency emission was direction dependant. Measurement points were where an air duct outlet or inlet was clearly visible.

Fig. 1 describes grain dryer's noise spectre in direction P1 (direction of main fan).

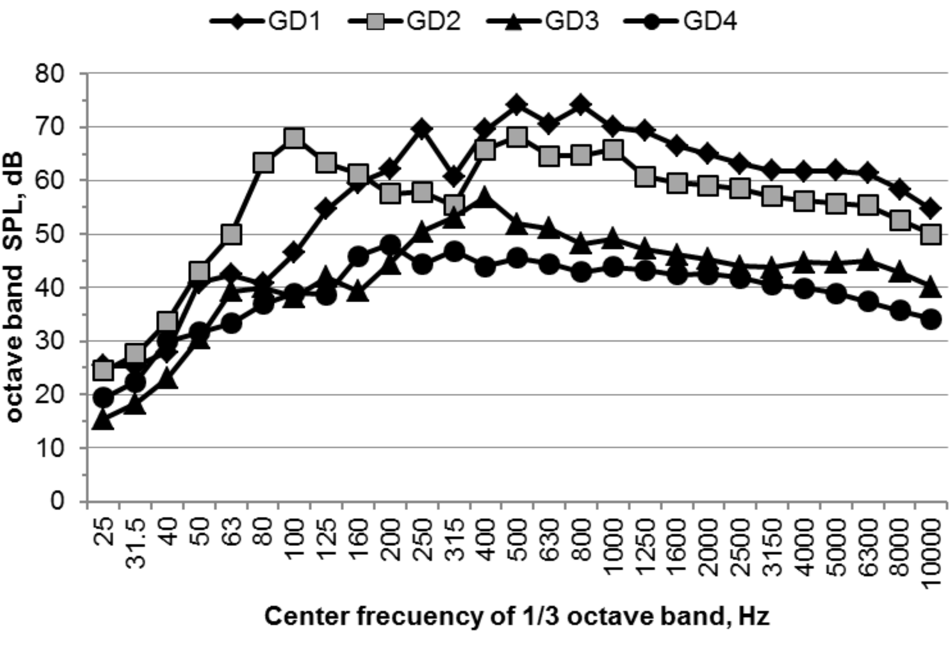

Figure 2. Grain dryer's noise spectre in P1.

It has been suggested that axial fans (operate around 3,000 rpm) are not generally suited for grain drying as they are (due to frequency response of human ear) noisier than centrifugal fans (1,500 rpm) (Bakker-Arkema et al., 1996). Therefore the frequency of distinctive tone from a centrifugal fan is expected to be a harmonic of 1500 : 60 = 25 Hz. Exact frequency depends on the number of fan blades.

Noise spectres of GD3 and GD4 are smooth. In GD2 there is an increase in octave band with centre frequency of 100 Hz, but the tonality criteria will not apply. In case of GD1 there is a clearly distinctive tone in the 250 Hz octave band. Therefore noise from GD1 is perceived as very annoying both by its SPL and tonal nature.

CONCLUSION

Grain dryer's SPL depends on the measurement direction. Therefore grain dryer layout must consider the location of surrounding homes or workplaces to avoid possible noise pollution. In case of a plain field the grain dryer's noise could be recognisable at almost 500 m.

Unnecessary expense of a muffler can be avoided if landscape information is taken into account. Potential economic effect could serve as a competitive advantage. However, the damping effect of vegetation must not be overestimated.

Further investigation about noise damping is needed as the effects of fan rotation speed, horizontal or vertical direction of air duct outlet, etc. remain unclear. Also the conditions which result in a clear audible tone should be explained in order avoid additional irritation to human ear.

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