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Comparison of the Odour Impact of Cattle Housing with and without an Outdoor Exercise Yard

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Exercise yards are increasingly being attached to cattle housing in order to provide the animals with additional space for movement and contact with the external climate. The use of exercise yards in addition to the loose house usually causes an expansion in the soiled and hence emission-active areas. Besides this, we are dealing here with emission sources close to the ground, which are particularly exposed. Exercise yards were not previously taken into account in Switzerland when calculating the minimum distance to residential zones.
The aim of this study was to highlight any effect of the exercise yard on odour impact by analysing an available dataset of loose houses with exercise yards using specific statistical methods. In addition, for comparison with an experimental approach, the odour impact of an exercise yard with free flow over a uniform surface was determined. To this end, cattle excrement was distributed over an area of 100 m^2. For the survey, ten dairy-cattle houses with exercise yards and isolated farm locations were selected. Nine farms had loose housing with resting cubicles and one had a deep-litter system. Eaves-to-ridge and forced-ventilation systems were all used. Animal populations varied between 20 and 40 livestock units. The emitting areas comprised 100 to 600 m², of which exercise yards accounted for between 50 and 180 m². The exercise yards had solid flooring and were permanently accessible.
For both the cattle housing and the test area, the odour impact was determined in the summer half-year by means of odour-plume inspections. Immediately after the first three inspection rounds, performed with a soiled exercise yard, the yard was covered with sheeting. Further inspections then followed, corresponding to the situation with no use of the exercise yard. Impact-side odour perception was recorded by trained assessors as odour intensity in intervals of ten seconds, via inspection rounds of ten minutes' duration each.
The statistical analysis of the dataset with a linear mixed-effects model took into account the hierarchical structure with farm and survey date. The impact-side odour intensity was explained by a model with the influencing variables area, distance to source and wind speed. The odour impact of the test area was explained by analogy using a model consisting of distance and wind speed. The results from the test area and the surveys on the cattle farms demonstrate the odour relevance of enlarged surfaces. Only an analysis taking account of the hierarchical data structure with repeated measurements and fixed and random effects made it possible to derive relevant influencing variables on odour release and dispersion. A differentiation and consideration of total odour-relevant areas, and hence of exercise yards, is indicated in future in distance recommendations, in order to prevent odour complaints.

1. Introduction

A wide variety of housing systems can be found in cattle farming, ranging from stanchion barns to loose houses to combinations with exercise yards. These are usually naturally ventilated systems. For cattle, there has previously been no differentiation by housing system in distance recommendations for livestock facilities in Switzerland (Richner und Schmidlin, 1995) and Germany (VDI guideline 3894, 2012). For example, VDI guideline 3894 (2012) cites a uniform odour emission factor of 12 OU/s·LSU for all cattle housing systems. In addition, no figures are available for outdoor runs (i.e. exercise yards). Due to measurement problems in determining air exchange rates, only values agreed by the experts are given; no systematic comparative studies have been conducted. Initial surveys by Keck et al. (2010) using a tracer ratio method in contemporary housing systems in five loose houses with exercise yards indicate higher odour emissions than in VDI guideline 3894 (2012). For up-to-date, sound planning data, an impact-side consideration of cattle farms should be included if possible. The literature does contain some surveys, but using different housing systems and substantially larger animal populations (over 1,000 dairy cows) (Sheffield et al., 2007). In addition, it has not really proved possible to integrate single-farm surveys to obtain generally valid conclusions and derive generally valid influencing variables (Jungbluth and Hartung, 1996).

The aim of this study was to highlight any effect of the exercise yard on odour impact by analysing an available dataset of loose houses with exercise yards using specific statistical methods. In addition, for comparison with an experimental approach, the odour impact of an exercise yard with free flow over a uniform surface was determined.

2. Materials and methods

The data basis used consisted of the surveys by Keck et al. (1999) in "Cattle housing systems with exercise yards: increased odour immission?" A comparison was made of odour intensity with and without use of the exercise yard within the individual farm. In comparison with indoor keeping, no difference in odour intensity was detected with use of an exercise yard. The wide variety and combined effects of the different influencing variables on odour intensity at varying distances from the livestock house could not be taken into account.

2.1 Overview of surveys

The surveys were conducted on ten cattle farms with a loose house and an adjoining solid-surfaced exercise yard. The farm sizes ranged from 11 to 44 cows. The odour-relevant area was determined by adding together the surface area of the feeding aisle, the cubicle access area, the cubicles, the exercise yard and the manure store. The total odour-relevant areas ranged from 100 to 600 m^2, of which exercise yards accounted for between 50 and 180 m^2. Further details of the farms, housing systems and ventilation methods are given in Table 1.

In addition, a 100 m^2 solid-surfaced test area was defined in each case and soiled with cattle excrement. The amount of excrement applied was in line with our own observations of excretory behaviour and measurements of excrement accumulation in an exercise yard.

Table 1: Overview of surveys

Description	Farms	Test area
Situation	10 cattle farms, 11-44 cows, some young stock, total 12-44 livestock units, loose house with cubicles (9 x) or deep litter (1 x), exercise yard with solid flooring, permanently accessible, manure store open or covered, 4 x forced, 6 x eaves-to-ridge ventilation, isolated farm situations	Solid flooring, soiled with cattle excrement on each survey day, free flow over a uniform surface, no obstacles in the environment
Areas	100-600 m^2 total odour-relevant area with feeding aisle, cubicle access area, cubicles, exercise yard and manure store, of which 50-180 m^2 exercise yard	100 m^2 exercise yard-test area
Survey procedure	Approx. 2 survey dates per farm, 20 survey days in summer half-year, in each case, 3 inspection rounds per farm with exercise yard soiled (i.e. "with exercise yard") and 3 inspection rounds with covered exercise yard (i.e. "without exercise yard"), assessors at 30-145 m distance from the farm	13 survey days, 3 inspection rounds per day Assessors at 15-70 m distance from the test area

2.2 Odour-plume inspections

Odour-plume inspections to determine the odour impact were conducted in summer half-year in each case on the test area and on each cattle farm (Table 1). Immediately after the first three inspection rounds, performed with a soiled exercise yard, the yard was covered with sheeting. Further inspections then followed, corresponding to the situation with no use of the exercise yard.

Five out of a total of 14 assessors were deployed in each inspection round. In three consecutive inspection rounds, the assessors were positioned at three different distances from the livestock house, in each case on lines perpendicular to the prevailing wind direction. Over a period of ten minutes, at ten-second intervals, they

recorded their odour impressions as an odour intensity between level 0 (not perceptible) and level 6 (extremely strong). In addition, the assessors' odour perception was checked at the olfactometer on each survey day with odour samples from the outdoor exercise yards.
Air temperature, air humidity, wind speed and wind direction were recorded during the inspections as descriptive parameters. The extent of soiling of the exercise yard was also assessed.

2.3 Statistics

After the data preparation, the descriptive parameters area, temperature, wind speed and distance were represented in graphic form. In each case the odour intensity was calculated as a mean value per inspection round and assessor. Based on the wide range of possible influencing variables, a linear mixed-effects model was created using RStudio, version 0.99.491 (Table 2). This model takes account of the hierarchical data structure of farm and survey day on the farm or of survey day on the test area as random effects. The collinearity of influencing variables (e.g. temperature, season) was taken into account. After several steps this produced a model for the farms with the target variable odour intensity, the intercept and the explanatory variables area, distance and wind speed. In the case of test area, the odour intensity was explained using distance and wind speed.

3. Results and discussion

3.1 Descriptive parameters

Figure 1 shows the descriptive parameters a) area, b) air temperature and c) wind speed during each inspection round on the farms. The total odour-relevant area on the farms ranged from 100 to 600 m^2. The exercise yard accounted for 23 to 52 % of the total odour-relevant area. On farm 8, only the situation with the outdoor exercise yard was recorded. The air temperature was between 8 and 29 °C on the farms and between 10 and 27 °C in the test area. The maximum wind speed was 16 m/s, with a mean wind speed of 4.3 m/s on the farms and 4.6 m/s in the test area.

3.2 Odour impact

The square root of the impact-side odour intensity was explained on the farms using a linear mixed-effects model with the parameters area, distance to source and wind speed (Table 2). By analogy, the square root of the odour intensity of the test area was explained using a model consisting of distance and wind speed. A higher odour intensity was found with larger odour-relevant areas and higher wind speeds, whereas odour intensity declined with increasing distance.

Table 2: Linear mixed-effects model to explain the square root of odour intensity based on odour-plume inspections on the farms and in the test area with the explanatory parameters, F and p values

Model	Parameter	Farm		Test area	
		F value	p value	F value	p value
Fixed effects	Intercept	0.5576	<0.0001	1.1652	<0.0001
	Area	0.0008	0.0085	--	--
	Distance	-0.0019	0.0215	-0.0074	0.0265
	Wind speed	0.0256	0.0459	0.0373	0.0311
Random effects		Farm			
		Survey day		Survey day	

Figure 2a) shows the mean odour intensity per inspection round in the situations with an exercise yard (filled dots) and the situations with a covered exercise yard (circles). The situation with an exercise yard and a larger area usually gave a higher level of odour intensity than the situation with a covered exercise yard and a smaller area. The odour intensity decreases with increasing distance to the farm (Figure 2b) and to the test area (Figure 2d). The assessors also recorded higher odour intensities at higher wind speeds (Figures 2c and 2e).

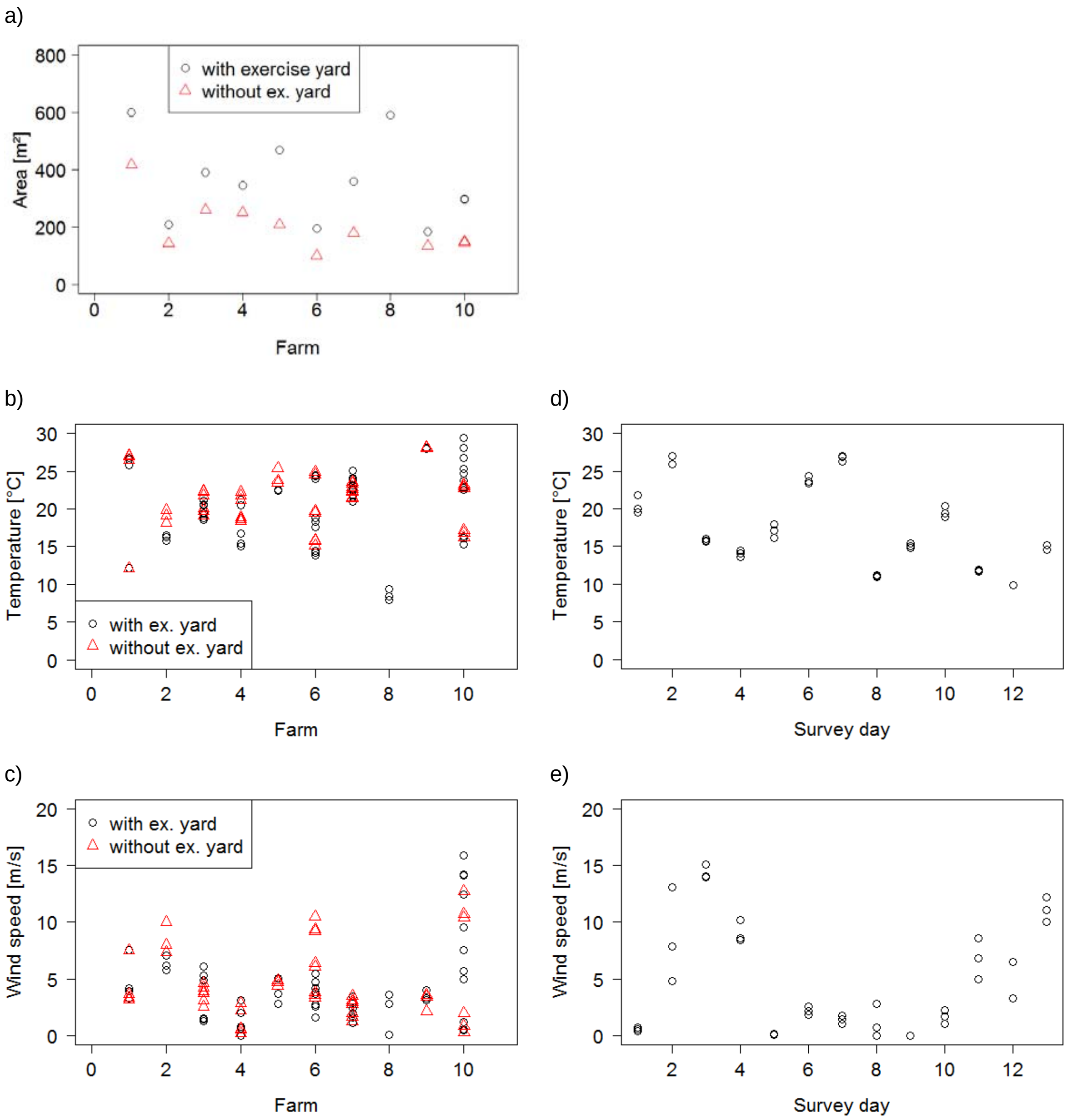

Figure 1: Descriptive parameters during the odour-plume inspections with information on a) areas of the farms with and without exercise yards, b) air temperature and c) wind speed on the farms, and d) air temperature and e) wind speed in the test area.

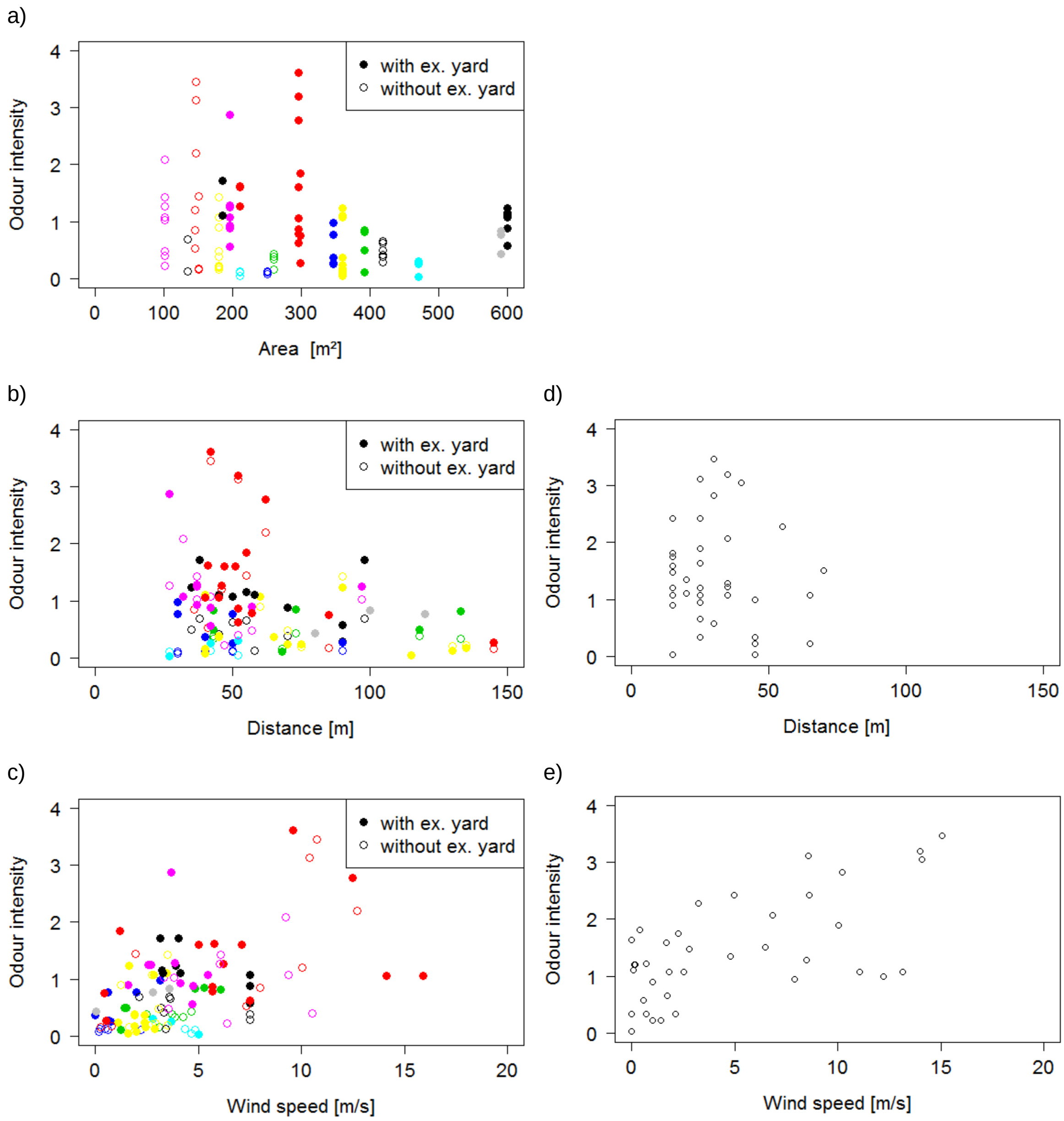

Figure 2: Odour intensity results per inspection round on the farms depending on a) area, b) distance and c) wind speed and in the test area depending on d) distance and e) wind speed. The different colours represent the data for individual farms.

4. Conclusions

The decline in odour with increasing distance and higher odour intensities at higher wind speeds were also found in pig farming (Keck et al., 2005) and on a farm with cattle and a biogas plant (Keck et al, 2014).

In the exercise yards with free flow over a uniform surface as well as on the ten farms, the same influencing variables explained the impact-side odour intensity. The odour intensity of the area with free flow over a uniform surface was higher, even where the area was only 100 m^2. This is partly explained by the effect of the buildings on the farms. Parts of the inspection positions, especially at close range, were still within the buildings' area of influence. Areas which are exposed to wind are relevant odour sources. Apart from the exercise yard, such areas include the silage store and manure store.

The results from the test area and the surveys on the cattle farms demonstrate the odour relevance of enlarged surfaces. For that reason, a differentiation by odour source and housing system is indicated in future in distance recommendations for cattle as well. The data basis should be expanded in a targeted manner with respect to odour-relevant single sources and whole-farm considerations.

Only an analysis taking account of the hierarchical data structure with repeated measurements and fixed and random effects made it possible to demonstrate relevant influencing variables on odour release and dispersion. The wide variety and combined effects of the different influencing variables on the impact-side odour perception of single sources and of overall systems should be considered in order to derive sound planning data.

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