Influence of Local Terrain on Odour Attenuation over Distance in a Dairy Farm with Biogas Plant

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ABSTRACT

The aim of this survey was to compare odour-attenuation behaviour over distance and in different directions on a farm with varying topography. For this, odour plume investigations were performed with six assessors on a dairy farm with biogas plant.

The animal enclosure was the largest structure of odour, with an emitting surface area of 985 m². In addition to this, there were the solid-manure store and the substrate store, with a total area of up to 186 m². The results of two survey days with a total of six inspection rounds in different directions and over varying terrain are presented here.

In reconciliation rounds, the odour perception of the assessors was synchronous, with slight discrepancies between odour intensities. The plume axis in each case was determined by the prevailing wind direction. A distinct gradient of odour frequency and intensity was detected within the positions of the plume axis on flat terrain. Additionally, in the direction with a hollow and subsequent crest, odour dispersion was shaped by the local terrain, and hence by flow. Flow around or above the hill led to differing odour dispersion. In the area where the terrain sloped upwards, higher odour frequencies and intensities were recorded at greater distances. Even the minor 10 m differences in level in this terrain structure and the hollow led to changes in odour dispersion. Attenuation behaviour over distance was not present to the same degree. In situations with hilly terrain, odour dispersion processes occur as a function of wind flow and terrain. Accordingly, when modelling dispersion processes, location-related weather data and high-spatial-resolution topography must be borne in mind. This site-specific influence of the local topography must be considered very carefully in the case of use and authorisation processes, in order to avoid odour lawsuits.

KEYWORDS: Local terrain, odour impact, odour intensity, odour plume investigation, topography, wind.

INTRODUCTION

Odour frequency and intensity decline with increasing distance from the odour sources. Distance recommendations and dispersion modelling are based on this principle. The attenuation behaviour in the odour plume can be determined with plume inspections (Keck *et al.* 2005; Guo *et al.* 2006).

Farms with animal husbandry and biogas plants are characterised by odour sources close to the ground. Depending on the nature of the odour sources, the structural and technical design of the individual sources, and the operational aspects, the individual site situation acquires great importance in terms of odour dispersion (Beck, 2009). In Switzerland, odour dispersion is influenced by sites with complex terrain, local wind systems (slope and valley winds) and cold-air outflow. Kost and Nielinger (2001) pointed out the clear importance of complex terrain and different source level in dispersion calculations. The manner in which topographic effects, and hence any local flows, impact odour dispersion has not yet been clarified. In these conditions, this can lead to a solely circular distance measurement no longer being sufficient.
Farmers, planners, the animal-housing construction sector, approval agencies and the public require resilient decision-making bases, including for sites with local flows, for the sake of investment security and to avoid odour complaints and lawsuits.

The aim of this survey was to compare odour-attenuation behaviour over distance and in different directions on a farm of varying topography. The survey was anchored in an eight-farm project recording the odourant concentration of individual sources in the area of the biogas plants and the animal housing (Keck et al., 2014a), as well as the odour impact of the plants as a whole (Keck et al, 2014b).

METHODS

The farm is situated 612 m above sea level in a hilly area (Figure 1). The land exhibits a slight downward slope towards the northeast and west of the farm. To the northwest and southeast of the farm the drop of the terrain is very shallow – around 10 m over a distance of 200 m. Hereinafter, such terrain will be described as flat. Towards the south, a slight hollow (605 m) is succeeded by a crest (631 m) at a distance of 300 m. The farm is surrounded by grassland.

The western section of the buildings comprised the animal housing, whilst the eastern section consisted of residential buildings. The farm investigated had 65 dairy cows, 30 head of young cattle and 15 fattening calves (Table 1). The animals were kept in naturally ventilated cubicle loose housing with outdoor exercise areas. The animal enclosure was the largest structure of odour, with an emitting surface area of 985 m²; in addition to this, there were the solid-manure store and the substrate store, with a total area of up to 186 m². The biogas plant encompassed a covered slurry store, a fermenter with a concrete lid, and a secondary fermenter with a double membrane. The liquid fermentation residue was stored uncovered in the elevated tank.

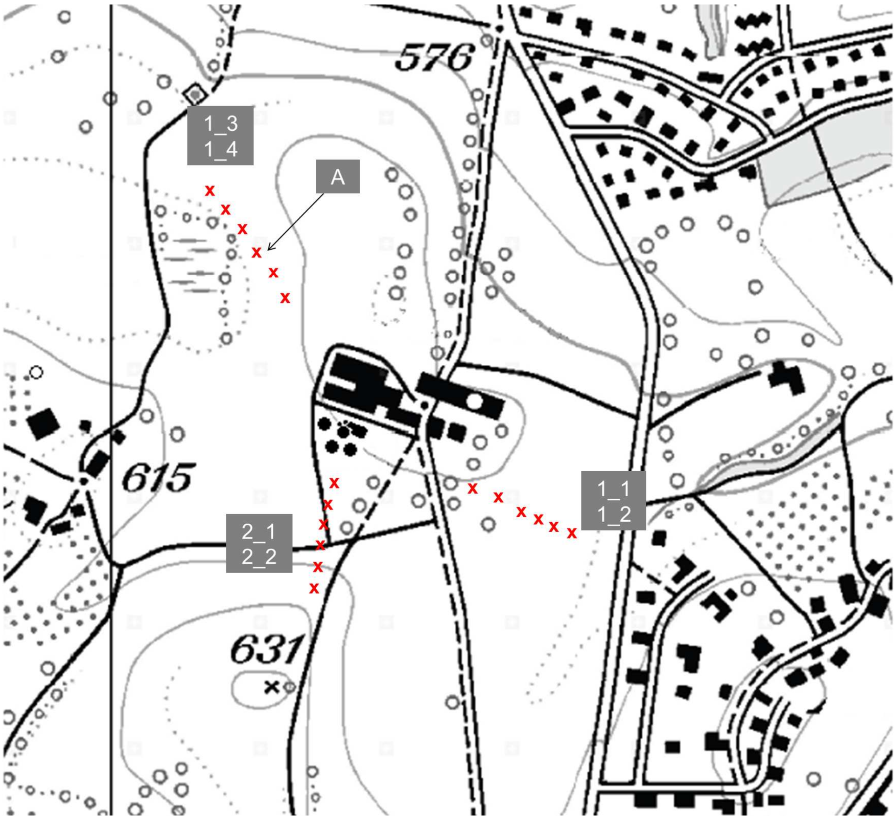

Figure 1. *Location of the farm with surroundings and the positions of the assessors (symbol x) during the field inspections as well as during the reconciliation round (A). Source: www.geo.admin.ch*

Table 1. *Details on the farm with animal husbandry, the individual sources in each case, and the size of the emitting area sources [m²].*

<u>Animal enclosure:</u> 985 m^2 **65 dairy cows,** **30 head of young cattle** Mixed feed ration Resting cubicles Solid-concrete floor surfaces Perforated floor surfaces Solid-concrete outdoor exercise area **18 and 13 fattening calves, respectively** Deep litter	**<u>Solid-manure store:</u>** **145 m^2, 44 m^2** Solid cattle manure **<u>Substrate store:</u> 41 m^2** Solid cattle, horse, poultry manure Cereal waste Grass cuttings Pomace	**<u>Biogas plant:</u>** Solids feed Fermenter with concrete lid Cogeneration unit Liquid fermentation residue store Secondary fermenter, gas store, double membrane

A weather station was used to collect temperature, wind speed and wind-direction data with a USA-3D anemometer by Metek. The wind data were recorded at a height of 10 m, at a distance of about 300 m from the farm.

Odour-plume inspections were performed on two different days by six assessors carrying out two to four inspection rounds in each case (VDI, 2010). Two situations were distinguished: substrate store open (+) or covered with plastic sheeting (-). The assessors recorded odour frequency and intensity at 10-second intervals over a period of 10 minutes per round. Odour intensities ranging from imperceptible (0) to extremely strong (6) were determined.

Prior to this, the assessors underwent a joint briefing with various olfactory tests in each case. To check their reactions, all assessors were first placed in the same position (Figure 1, A). This served as an opportunity for the assessors to reconcile their individual perceptions of odour intensity, and as a test of synchronous reaction. During the following inspection rounds, the six assessors were positioned in a row one behind the other facing the then-prevailing wind direction, and hence in the plume axis. A distinct gradient of odour frequency and intensity within the positions of the plume axis was essential in order to enable recording of the attenuation behaviour along the odour plume.

RESULTS AND DISCUSSION

Positioning the assessors next to each other in the same place (Figure 1, A) allowed the temporal progress of their odour perception and their odour intensity ratings to be compared (Figure 2). A comparison of the results between the assessors shows the synchronous progress of their odour perception, with e.g. all six assessors perceiving no odour in intervals 33 and 34, whilst all assessors detected an odour in intervals 6, 8, 10 and 11, as well as in 20 to 22. Odour intensity ratings deviated by about one level up or down. A synchronous progress with slight differences between the individual intensity levels was determined as a summary of the reconciliation rounds. The reconciliation provides clues as to the agreement between the individuals. Odour recording in the field with intensity levels enables a more differentiated survey than does the method of answering “yes” or “no” to the question of whether something smells.

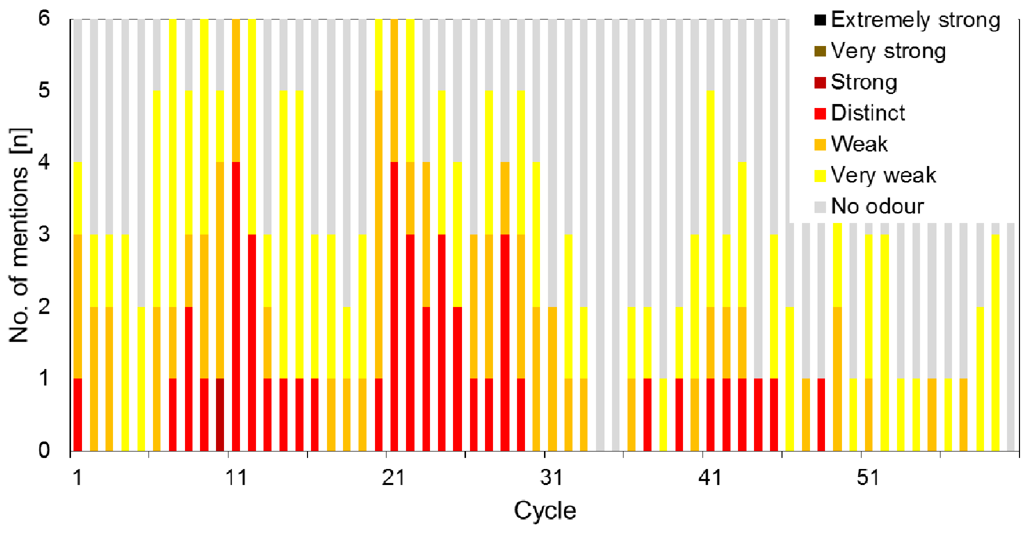

Figure 2. *Number of mentions of the individual intensity levels per 10-second cycle during a reconciliation round for comparing the responses of assessors 1 to 6 in the same place.*

Figure 3 illustrates the progress of air temperature, wind speed and wind direction during the individual inspection rounds. The temperature varied only within a very narrow range between 9.5 and 13 °C. Both wind speed and wind direction were similar in the two sequential inspection rounds in each case (1_1 and 1_2, 1_3 and 1_4 as well as 2_1 and 2_2). The plume axis in each instance was determined by the prevailing wind direction. Accordingly, the assessors were positioned in the plume axis.

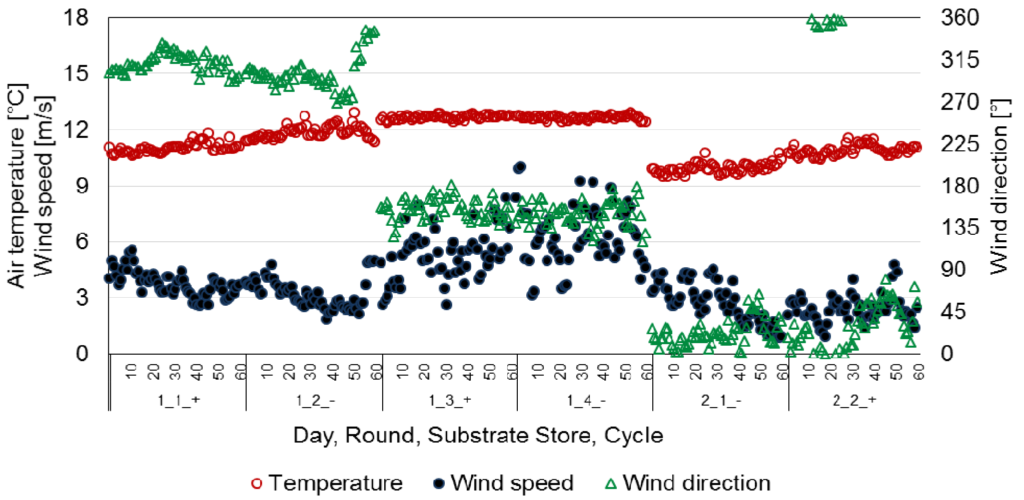

***Figure 3**. Course of air temperature [°C], wind speed [m/s] and wind direction during the inspection rounds for each 10-second interval.*

If the assessors were positioned consecutively in the prevailing odour plume (southeast of the farm, round 1_1 and round 1_2; northwest of the farm, round 1_3 and round 1_4) at approximately the same height but at various distances from the farm (Figure 1), these four inspection rounds showed a resultant distinct attenuation of average odour intensity with increasing distance (Figure 4). The assessors near the plant recorded a noticeably higher average odour intensity than those positioned farther away. In the two inspection rounds 1_3 and 1_4 with wind speeds of over 5 m/s, the average odour intensity reached values of above three at a distance of approx. 100 m from the plant. If the odour plume proceeded in a southerly direction (round 2_1 and round 2_2), the assessors positioned closer to the biogas plant noted lower odour intensities at a distance of between 130 and 165 m than both the assessors at a greater distance (over 200 m) and the assessors in the front positions on flat terrain. No distinction in odour owing to the substrate store, either open (+) or covered with plastic sheeting (-), was detectable.

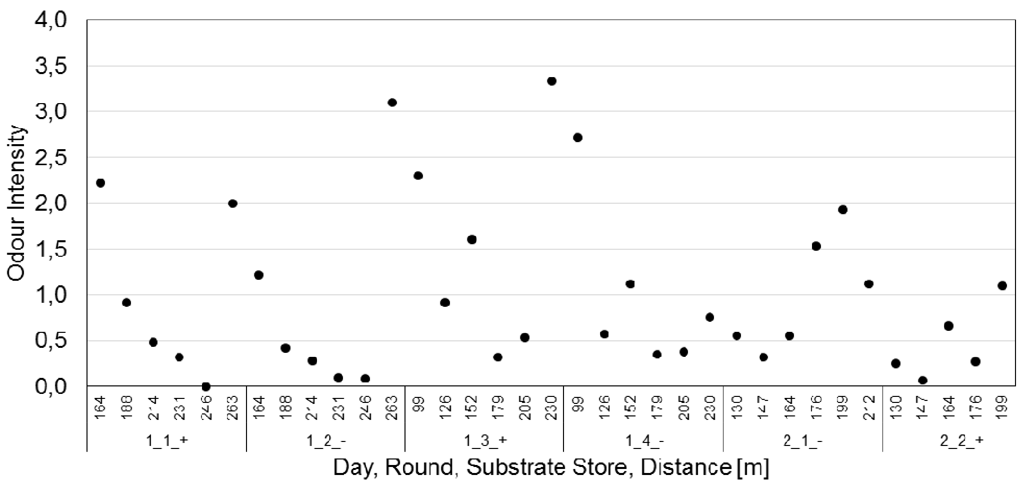

***Figure 4**. Mean value of the odour intensity per assessor according to distance [m] per survey day and inspection round in the situation with open (+) or covered (-) substrate store.*

Figure 5 highlights the distribution of odour intensities according to day, round, and distance from source. Whereas day 1 saw a high percentage (80-100 %) of time when odour was perceived as well as higher odour intensities (very strong to weak) in all inspection rounds (1_1 to 1_4) in the front positions on flat terrain, this pattern was no longer apparent on day 2 on hilly terrain. Odour frequency and odour intensities were lower in the hollow, even in the front positions, but were still high in the more distant positions 200 m away. Averaging 2.8 m/s and 2.4 m/s, the wind speed in this situation was low, despite which the odour range was still high.

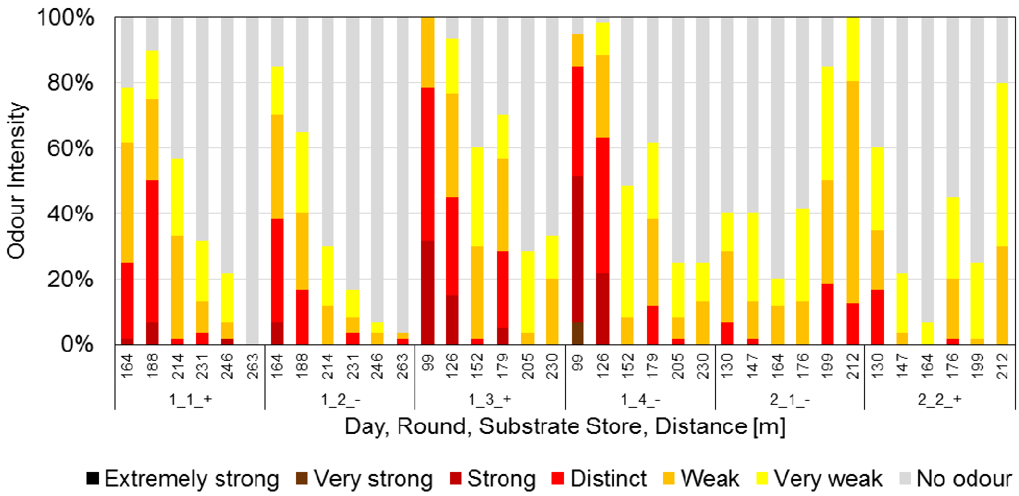

***Figure 5**. Relative frequency of odour intensities [%] per assessor according to distance [m]and inspection round in the situation with open (+) or covered (-) substrate store on day 1 at the same height and on day 2 in the direction of a hollow and subsequent hill.*

The plume inspection method for determining odour attenuation behaviour over distance is suited to flat terrain. In the situation with hilly terrain, local flow processes shaped by the local topography exercised an effect. Even the minor 10 m differences in height in this terrain structure as well as the hollow led to changes in odour dispersion. There was no longer the same sort of attenuation behaviour over distance. In the area where the terrain sloped upwards, higher odour frequencies and intensities were recorded.

CONCLUSIONS

The inspection rounds conducted on flat terrain showed a significant attenuation in odour intensity over distance, owing to the prevailing wind direction in the plume axis. In the situation with a hollow and subsequent crest, however, odour dispersion was shaped by the local terrain, and hence by flow.

Near-ground-level odour dispersion is also shaped by the topography of the site in question. At a greater distance, odour was still perceptible with higher frequency and intensity. This site-specific influence of the local topography must be considered very carefully in use and authorisation processes, in order to avoid odour lawsuits.

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