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Odour Impact by Field Inspections: Method and Results from an Agricultural Biogas Facility

Margret Keck*, Markus Keller, Matthias Frei, Sabine Schrade

Agroscope, Institute for Sustainability Sciences ISS, Taenikon 1, CH-8356 Ettenhausen
margret.keck@agroscope.admin.ch

Agricultural biogas facilities in Switzerland generally complement livestock farms. Facilities in the vicinity of residential areas can cause residents to complain about odours. Area sources include storage facilities of substrates, fermentation residues, the animal housing and outdoor exercise areas, feed and manure stores. Biogas can also escape directly from the facility.
The aim of these investigations was to examine the odour impact of the farm as a whole in relation to the decay behaviour of the odour plume, with a view to determining the requisite distance to residential areas.
Plume inspections of the ambient air on a dairy farm with a biogas facility were carried out on three days during the summer and transitional period, in each case in the afternoon and evening. Six assessors at various distances from the farm registered their odour perception at 10-second intervals.
The odour intensity distribution of the assessors during individual field inspections is presented: high percentage odour times with high odour intensities are ascertained at positions close to the farm. As the distance increases, there is a noticeable reduction in percentage times with odour as well as a decrease in the high intensity levels. The higher the wind speed, the further the odour reaches and the more intense it is perceived. Biogas leakage situations further increase the effect. Biogas odour is rated as definitely unpleasant by the assessors.
Compared with grid inspections the decay behaviour of odour could be determined much more efficiently by focussing on the odour plume. As a precaution, it is advisable to take great care when selecting the location for new agricultural biogas facilities, usually as an addition to livestock farms. Distances to residential areas should be adequately assessed. Process optimisation and maintenance should be addressed in order to prevent biogas leakage.

1. Introduction

Since the year 2000, the number of agricultural biogas facilities in Switzerland has risen from about 60 to more than 80 facilities. A systematic survey of 38 biogas operators showed that the biogas facilities in Switzerland differ greatly in terms of system and process technology as well as substrates. Nearly all of the farms surveyed kept livestock in addition to the biogas facility (Mager et al., 2011). Area sources in the biogas plant zone include storage facilities of substrates and fermentation residues. Additional odour sources are the animal housing and exercise yard areas, feed and manure stores on the livestock farm. Agricultural biogas facilities close to residential buildings may cause an odour nuisance for the residents. Information on the odour nuisance from biogas facilities was provided by Liebich (2009) and Beck (2009). The short distance of a large number of the biogas facilities in the survey to residential buildings underlines the need for sound data on which to base the planning and operation of agricultural biogas facilities.
In investigations on the concentration of odour and a marker in ambient air from a biofilter in a municipal waste treatment plant with an anaerobic digestion system in Italy, the concentration in the odour plume was lower the further it was from the source. This effect could be seen with three methods used: portable olfactometer Scentroid SM110, “Nasal Ranger” field olfactometer and markers chemical analysis (Benzo et al., 2012). In field inspections with grid measurements on another Italian municipal waste treatment plant with an anaerobic digestion system, the assessors had to document odour type, making a distinction between “biogas”, “biofilter” and “green waste”. It was sometimes difficult to differentiate between the types

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of odour because, in the ambient air, the assessors often perceived a mixed odour made up from the different sources (Benzo et al., 2010).

Ubeda et al. (2010) performed odour investigations of a dairy farm with anaerobic digestion in Belgium. The odour emission rate from the different area sources was determined using dynamic olfactometry. Agricultural liquid and solid wastes displayed much higher odour emission rates than the area sources of dairy barn, digested waste and corn silage. According to the plume extent determined by field inspections with a zig-zag movement around the axis of the plume as well as according to dispersion modelling, the plume was over 400 m long (Ubeda et al., 2010). Nicolas et al. (2013) used field inspections and back-calculation to assess the global odour emission rate of three farms with biogas plants located in Belgium, Luxemburg and Germany. The maximum odour perception distance from a total of eight days of investigation was between 300 and 600 m (Nicolas et al., 2013). To date there have not been any scientifically established data that can be used as a basis for recommending minimum distances for agricultural biogas facilities in Switzerland with regard to suitable reduction measures.

The objective of the investigation was to examine odour impact from an entire farm with livestock and biogas facility with regard to the necessary distances to residential areas and to derive reduction approaches. To do this, systematic odour investigations were performed on eight farms with agricultural biogas facilities and livestock in Switzerland. The method chosen and selected results from a dairy farm with a biogas facility are presented here.

2. Materials and methods

2.1 Site description

The inspections were performed on a total of three dates during the summer and transitional period of 2012 on a dairy farm with an agricultural biogas facility. The cows were kept in naturally ventilated dairy cubicle housing with an outdoor exercise area. The biogas facility was operated in two stages with a fermenter and a secondary fermentation device. In addition to manure, mainly vegetable and fruit waste were used in the biogas facility. On all of the inspection dates, the size of the emitting areas was dominated by the livestock area with 88 to 92 % compared to the solid manure store (1-4 %) and the substrate store (5-8 %).

2.2 Measurements and methods

The objective of the plume inspections was to record the odour impact of the entire farm with the area sources of livestock, manure and substrate stores. During the inspections, no short-term special activities were allowed to be carried out, such as feed distribution, dung removal, delivering substrates, solids-based feeding, stirring slurry, etc. On every date, one block each was executed with single measurements in the afternoon and in the evening. The assessors were examined according to the requirements of EN 13725 (2003) on the TO8 olfactometer (ECOMA, Honigsee, G) with n-Butanol. For training purposes, the assessors were presented with selectively different odour samples before each block of inspections began. There was also a coordination measurement to compare odour intensities between the assessors and as a test for the synchronous reaction.

In each case, the position of the odour plume was indicated with wind vanes or smoke samples. Six assessors were positioned in a line, one behind the other, in the direction of the currently prevailing plume axis. The distance between the assessors and the distance of the first tester assessors from the farm was determined according to wind and source strength (Fig. 1). A single measurement lasted ten minutes. To be able to record decay behaviour along the odour plume, there had to be a clear gradient of odour frequency and intensity between the positions. If the wind direction changed during a single measurement, only the previous data were used, the testers were positioned in the new direction and additional measurements started. The assessors recorded their perception of odour as intensity every ten seconds. Data was entered on a handheld PC PDA Asus P552w with MF3 V2.1 software from ECOMA (Honigsee, G) or a Psion Serie 3a with Olfacto software from ECOMA (Honigsee, G). Odour intensity was documented on a 7-level category scale from “0” (imperceptible) to “6” (extremely strong) on the basis of VDI 3940, Part 3 (VDI 2010a). Because mostly mixed odours were to be expected in the case of agricultural operations with livestock farming and a biogas facility and because of the large number of various odour sources, the intensity scale was defined differently from VDI 3940. For example, the level “1 very weak” was selected as soon as it was first detected, but not only when the recognition threshold was exceeded. Then, in each measurement, the assessors made notes on their location, the quality and type of odour and its frequency.

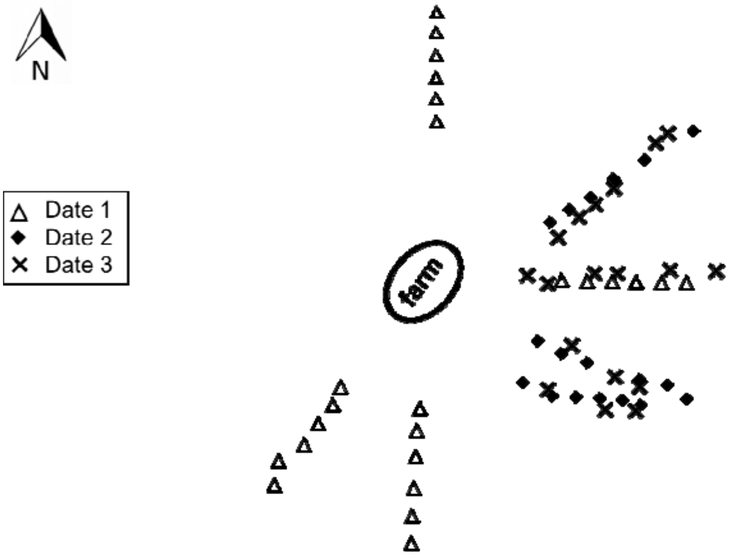

Figure 1: Diagram showing the positions of the field inspections on each inspection date.

During the plume inspections, a mobile weather station was used to record wind speed, wind direction, global radiation, air temperature and relative humidity. The weather station was positioned 100 m from the farm, away from any influence from buildings, trees or woodland.

3. Results and discussion

Table 1 gives an overview of the distribution of the 22 single measurements performed in total over the three inspection dates and two times of day, together with meteorological data. The temperatures ranged from 12 to 20 °C and were therefore within a narrow range. The wind speed was always lower in the evening than in the afternoon. In some single measurements in the evening, the wind direction, measured at a height of 10 m, was not the same as the local flow close to the ground.
Over all of the dates it can be clearly seen that the mean odour intensity fades the further away it is (Fig. 2). High odour intensities occurred more frequently with shorter distances than with larger distances. The full range of the odour plume might not be completely shown for individual inspections as, because of local conditions (high vegetation, roads, etc.), it was not always possible to place the furthest assessor outside of the plume. Whether the actual range of the odour plume was much larger in individual situations, cannot be conclusively determined afterwards. Because the values shown are averages over ten minutes, more individual values occurred with higher intensities every ten seconds. In the case of average values with very high intensities, the odour perceived over the inspection time was therefore constantly high.

Table 1: Details of the field inspections according to date and time of day: Number of measurements with a duration of 10 min that can be assessed [n]; minimum and maximum mean values from each measurement for temperature [°C] and wind speed [m/s] as well as wind direction.

Inspection date, time of day	Number of measurements [n]	Temperature [°C]	Wind speed [m/s]	Wind direction
1, Afternoon	2	12-14	1.5-2.4	West, South
1, Evening	5	12-14	0.4-1.4	East, Southeast
2, Afternoon	4	19-20	3.8-5.2	Southwest, West
2, Evening	4	19-20	0.7-3.1	Northwest, West
3, Afternoon	5	14-15	2.1-3.3	Northwest, West
3, Evening	2	15	0.8-0.9	South

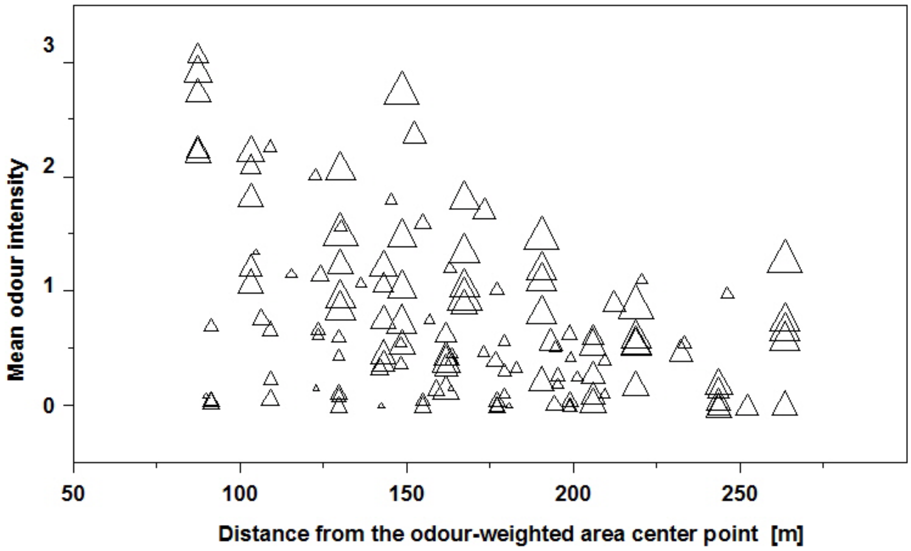

Figure 2: Mean values of odour intensity per assessor and single inspection measurement according to the distance from the odour-weighted area centre point [m]. The symbol size increases with the wind speed in a range from 0.7 to 4.0 m s^{-1} linearly.

As the distance increased there was a noticeable reduction in percentage times with odour as well as a decrease in the high intensity levels. For example, Figure 3 shows the distribution of odour intensities 1 to 6 for the six assessors over four single measurements in the afternoon of the third inspection date. In each case the values are aggregated over ten minutes. The distance of the six assessors from the odour-weighted area centre point was 86 m for the first assessor and 243 m for the last assessor. While the assessor in the first position perceived odour for 80 to 100 % of the investigation interval, assessor 6 did not document any odour in two single measurements and only intensities “1 very weak” and “2 weak” in two measurements. Intensity level 5 only occurred at the first two positions.

A highly significant influence of distance on odour perception was also found in investigations in pig housing systems with outdoor exercise areas (Keck et al., 2005).

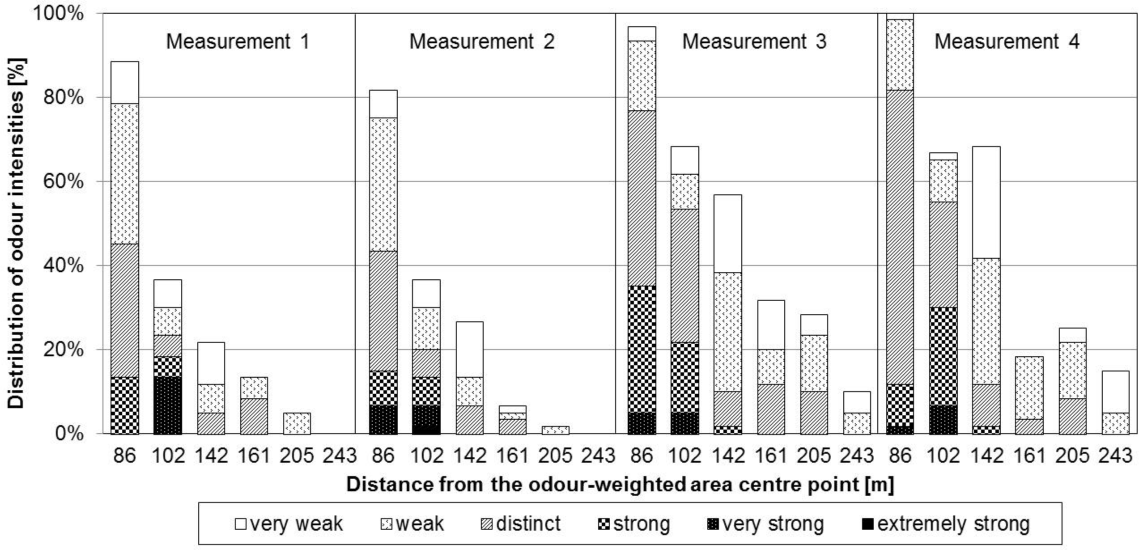

Figure 3: Distribution of odour intensities 1 to 6, aggregated over ten minutes in each case; assessors at six different distances from the odour-weighted area centre point over four single inspection measurements.

The higher the wind speed, the further the odour reached and the more intense it was perceived. The effect of wind speed is shown in Figure 2. The tendency is for higher odour intensities to be accompanied by higher wind speeds. At great distances odour occurred almost exclusively with higher wind speeds.
An effect of wind speed on odour impact was also found in plume inspections in pig housing systems with outdoor exercise areas (Keck et al., 2005) and in investigations on dairy housing systems with outdoor exercise areas (Keck et al., 1999).
During the field inspections biogas odour was registered very frequently by the assessors on all inspection dates and times of day. The assessors seldom documented other facility odours such as manure or location-related odours such as crops, car exhaust, meadow, etc.
Biogas odour was rated as hedonically definitely unpleasant by all of the assessors. Figure 4 depicts the theoretical polarity profiles for the concepts of fragrance and stench as well as the facility odour biogas, as average values from 19 assessors. Representative profiles of the concepts of fragrance and stench according to VDI Guideline 3940, Part 4 (VDI 2010c) are given for comparison purposes. The average value of the facility odour biogas across all properties and assessors is -1.5 and therefore definitely within the range of unpleasant odour.
The odour concentration of biogas samples from our own investigations with 28,000 to around 250,000 GE/m^3 and from the literature with around 270,000 GE/m^3 (Brun and Völlmecke, 2008) and 500,000 GE/m^3 (Liebich, 2004) also shows the relevance of biogas odour. Based on impressions during our own investigations and on the literature, frequent sources of biogas discharge are leaks, gas storage membranes and carrier air, pressure relief valves, inspection windows, stirring equipment openings, etc. (amongst others Bayerisches Landesamt für Umwelt, 2007, 2011; Beck, 2009; Sax et al., 2013; Weber et al., 2006).

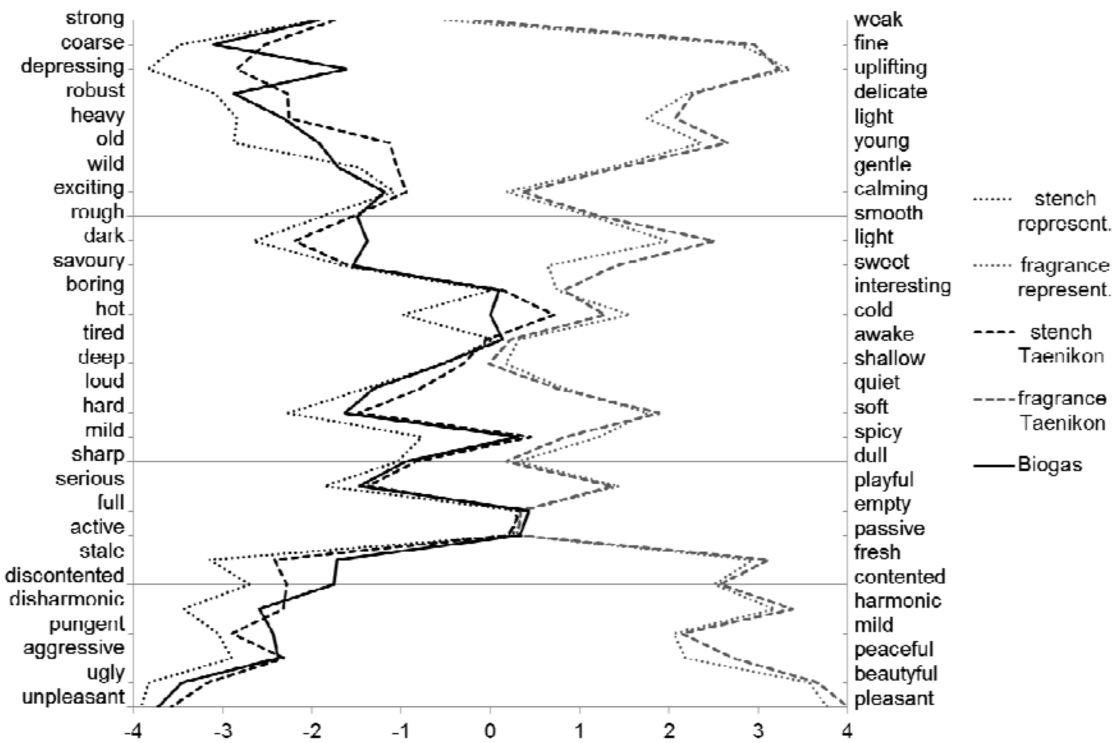

Figure 4: Polarity profiles for fragrance and stench and also biogas shown as average values from 19 assessors, and representative fragrance and stench profiles according to VDI 3940, Part 4 (2010b).

4. Conclusions

As far as the investigation approach is concerned, field inspections with assessors positioned in the plume axis have proved useful. The decay behavior of odour could be determined much more efficiently by focusing on the odour plume, instead of using grid measurements. Only by positioning the assessors in the axis of the plume was it possible to draw conclusions on the extent and decay behaviour of odour impact with distance. As a precaution, it is advisable to take great care when selecting the location for new agricultural biogas facilities, usually as an addition to livestock farms. Distances to residential areas should be adequately assessed. Biogas facility and livestock farming must be considered as a whole. Process optimisation and maintenance should be undertaken in order to prevent the emission of unpleasant biogas odour. Also, biogas losses through the gas storage membranes or leakages can be prevented by regular inspections and replacing parts when necessary.

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