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Odour Concentration of Agricultural Biogas Facilities: Substrates and Biogas

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Abstract

Agricultural biogas facilities in proximity to residential areas can lead to complaints from neighbours about odour. A survey showed a broad heterogeneity as regards systems and process engineering, as well as a wide diversity of substrates. The primary substrates are farmyard manure, crop residue, waste material from foodstuffs processing and green waste. The area sources in relation to the biogas plant include the storage of substrates and fermentation residue. Moreover, biogas may emanate directly from the facility, sometimes as an active point source or a passive diffusion source.

The aim of these investigations was to identify relevant diffusion sources in the area of the biogas facilities and to quantify their odour concentration. This survey is part of a project in which, in addition to the individual sources relating to the biogas facilities, the sources as regards animal husbandry and the odour impact of the farms overall were to be quantified. Notes on odour reduction are intended to act as a basis for decisions on facilities planning.

Investigations took place in relation to the individual sources on eight farms in Switzerland with agricultural biogas installations and animal husbandry, on two to four survey dates per farm in each case. In the case of passive sources, sampling took place using flow-through hoods. Additionally, at four facilities sampling bags were filled directly with biogas. The odour concentration was obtained on the same day by olfactometric analysis.

The areas from the animal husbandry sector were, with the exception of one farm, far larger than the substrate and fermentation residue areas. In addition to cattle slurry, substrates in the form of solid manure from beef cattle, horses and poultry as well as cereal waste, grass, brush or meadow cuttings and vegetable peelings frequently occurred. A higher odour concentration resulted from solid poultry manure, as opposed to solid manure from cattle and horses. Compared with cereal waste grass cuttings, vegetable peelings, liquid silage effluent and fermentation residue were sources with higher odour concentration and/or higher variation. The odour concentrations of the biogas samples were considerably above the majority of the odour concentrations of the substrates.

With reference to odour reduction, it is important to start with high-intensity odour area sources. Thereby, emitting surfaces must be kept to a minimum as regards duration of storage of substrates. Protection against the sun, wind and precipitation should be provided by means of housing and covering. Surfaces with liquid silage effluent should be avoided and any such drained off quickly. Fresh surfaces should be kept small and movements of material minimised. The escape of biogas must be prevented by ensuring adequate storage volume, process optimisation, maintenance, regular control and a redundant gas recycling facility. Concerning the required distances to residential areas, an overall consideration of biogas facility and animal husbandry is essential in relation to odour impact.

Keywords: biogas, substrate, fermentation residue, area source, odour concentration

1. Introduction

Agricultural biogas facilities in proximity to residential areas can lead to complaints from neighbours about odour. A survey carried out involving 38 operators in Switzerland showed a broad heterogeneity as regards systems and process engineering, as well as a wide diversity of substrates (Mager, Keck, Schrade, 2011). The primary substrates are farmyard manure, crop residue, waste material from foodstuffs processing and green waste. The area sources in relation to the biogas plant include the storage of substrates and fermentation residue. From the animal husbandry sector come, in addition, odours emitted from pens and outdoor exercise areas, feed and manure heaps. Moreover, biogas may emanate directly from the facility, sometimes as an active point source or a passive diffusion source.
The lack of systematic data about odour concentrations from area sources of biogas facilities complicates established planning recommendations to prevent and reduce odour impact.
The aim of these investigations was to identify relevant diffusion sources in the area of the biogas facilities and to quantify their odour concentration. This survey is part of a project in which, in addition to the individual sources relating to the biogas facilities, the sources as regards animal husbandry and the odour impact of the farms overall were to be quantified. Notes on odour reduction are intended to act as a basis for decisions on facilities planning.

2. Materials and methods

Investigations took place in relation to the individual sources on eight farms in Switzerland with agricultural biogas facilities and animal husbandry, on two to four survey dates per farm in each case. The study was carried out on 25 days from May 2011 to September 2012, during the summer and transitional period.
The storage of solid substrates was performed with façades at three or at least at one side, without a cover (farm A, B, G, H), partly covered (farm C, F) or covered (farm D, I) (Table 1). Farm D, F and G had solid fermentation residues, covered by a roof. The total size of the emitting surface of the entire farms with animal husbandry and biogas facility varied between 475 m² and 1811 m². The proportion of the storage of solid substrates and solid fermentation residue ranged from two to 59 %. To the animal husbandry sector belong, in addition, pens and outdoor exercise areas, feed and manure heaps.

Table 1: Description of farms by layout of the storage facilities of solid substrates and solid fermentation residues, size of total emitting surface [m²] and proportion of substrates and fermentation residues [%] (n.a. = not available; min = minimum; max = maximum).

	Layout of the storage facilities Cover / number of façades [n]		**Emitting surface of the whole farm**	**…of which solid substrates and fermentation residues**
Farm	Solid substrates	Solid fermentation residues	Total size [m²] min-max	Proportion [%] min-max
A	open (1)	n.a.	794-1173	2-4
B	open (1)	n.a.	684-822	6-9
C	roof; open (3; 2)	n.a.	1283-1452	8-9
D	roof (3)	roof (3)	475-627	13-34
F	roof; open (3; 1)	roof (1)	1222-1269	57-59
G	open (1)	roof (3)	1096-1205	16-23
H	open (1)	n.a.	777-813	5-8
I	roof (3)	n.a.	1776-1811	5-7

In the case of passive area sources, sampling took place using flow-through hoods EVH (dimensions 1030 mm x 530 mm) and underpressure samplers with integrated pump CSD 30 (ECOMA, Honigsee, D) according to VDI 3880 (2011). The supplied air had to be odour-neutral with an activated carbon filter. The sample bags consisted of polyethylene terephthalate (Nalophan®) with a volume of 8 l. Sampling duration was 10, 15 or 30 minutes. As far as homogeneous area sources were concerned, individual samples were taken whilst mixed samples were taken for heterogeneous sources at up to three locations. Additionally, at four facilities (farms D, G, H and J) sampling bags were filled directly with biogas at overpressure.

To prevent changes in the samples during storage, a bag-in-bag-system was used and olfactometric analysis was realized within the same day. The period between sampling and measurement varied between two and nine hours. The odour concentration was determined at the TO8 olfactometer (ECOMA, Honigsee, D) by four assessors each. The assessors were examined according to the requirements of EN 13725 (2003) with n-butanol and additionally checked with hydrogen sulphide and further typical odour qualities from livestock production.
A variety of accompanying parameters was used to characterise each measuring situation and to derive the relevant influencing variables. In the case of mixtures, the proportion of individual constituents was estimated. Quantification of the size of the emitting area of the individual sources was performed by a laser sensor. Temperature was quantified in the air above the substrates and 20 cm below the substrate surface. The dry matter content was determined by each substrate. The exposition of each substrate was rated: open - closed, shadow - sun.

3. Results and discussions

The incidence of the individual substrates as well as their size varied between individual farms and survey dates. The areas from the animal husbandry sector were, with the exception of one, far larger than the substrate and fermentation residue areas. In addition to cattle slurry, substrates in the form of solid manure from beef cattle, horses and poultry as well as cereal waste, meadow and grass cuttings, vegetable peelings frequently occurred.
The air temperature varied during sampling between 9 and 38℃ (Table 2). In many cases the substrate temperature 20 cm below the surface was much higher than the air temperature, in some cases up to fourfold. This effect was seen in solid manure from cattle and horses, meadow cuttings and solid fermentation residues. Figure 2 shows the odour concentration of solid manure from horse and cattle as a function of the temperature in 20 cm depth of the substrate. At a lower substrate temperature level (40 ℃), higher odour concentrations didn't occur.

*Table 2: Overview of accompanying parameters of solid substrates and solid fermentation residues: air temperature [℃], substrate temperature in 20 c m depth [℃] and dry matter content [%] with the range from minimum to maximum (min-max); *) single value.*

Substrate	Air temperature [℃]	Substrate temperature [℃]	Dry matter content [%]
Solid cattle manure	14-31	26-61	28-42
Solid horse manure	16-25	15-73	20-75
Solid poultry manure	23-26	16-42	51-73
Cereal waste	9-38	20-48	82-88
Meadow cuttings	16-20	23-65	38*)
Grass cuttings	16-28	24-49	21-27
Vegetable peelings	13-25	17-42	16-19
Liquid silage effluent	20-25	11-24	11*)
Solid fermentation residue	17-25	16-68	31-33

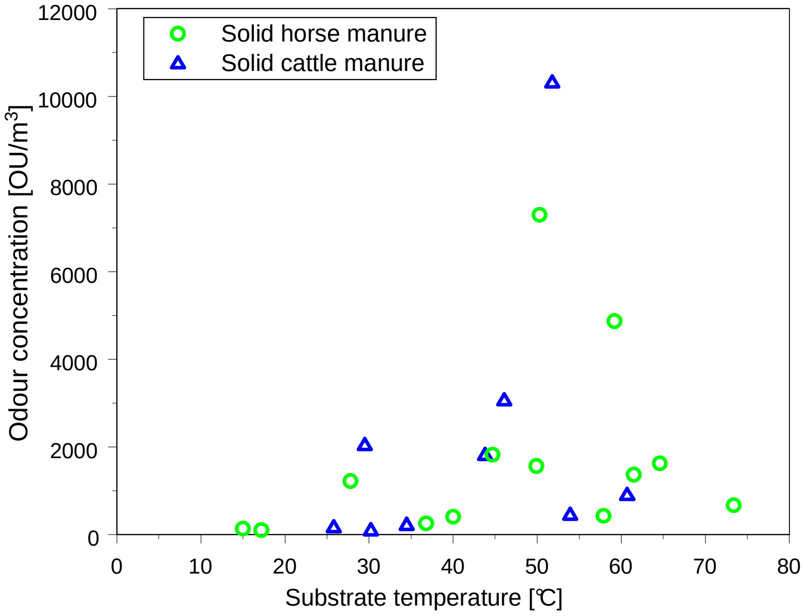

Figure 1: Solid manure from horses and cattle: odour concentration in odour units per m³ [OU/m³] as a function of substrate temperature [℃].

As shown in Figure 2, the highest odour concentration resulted from solid poultry manure (minimum - maximum 724-24 548 OU/m³), compared with solid manure from cattle (102-10 321 OU/m³) and horses (101-7298 OU/m³). Cereal waste was characterised by a very low odour concentration with 152-861 OU/m³. Meadow (96-9742 OU/m³) and grass cuttings (966-21 870 OU/m³) as well as vegetable peelings (483-14 597 OU/m³) were sources with a higher odour concentration and a big variation between the individual samples. Liquid silage effluent (683-4871 OU/m³) and solid fermentation residues (114-13 777 OU/m³) were characterized by higher odour concentration and/or higher variation.

From solid manure of poultry, this study revealed a higher odour concentration (median 6890 OU/m³) in comparison with one individual sample of Hunkeler and Stoll (2011) of only 210 OU/m³. The median of vegetable peelings (1991 OU/m³) was much higher than the individual sample of Hunkeler and Stoll (2011) with 540 OU/m³ for salad and garbage. The odour concentration of solid fermentation residues varied in this study between 170 and 13 780 OU/m³ (median 800 OU/m³) considerably more compared with values from Plätzer (200-1100 OU/m³; 2008) and Hunkeler and Stoll (360-1020 OU/m³; 2011).

As shown for solid manure of horses and cattle, but also for solid fermentation residues, grass and meadow cuttings, increased substrate temperatures can impact higher odour concentrations. Whereas cereal waste is characterized by a high dry matter content (82.4-87.5 %) and low odour concentration, vegetable peelings show the reverse effect with a dry matter of 15.8-19.2 %.

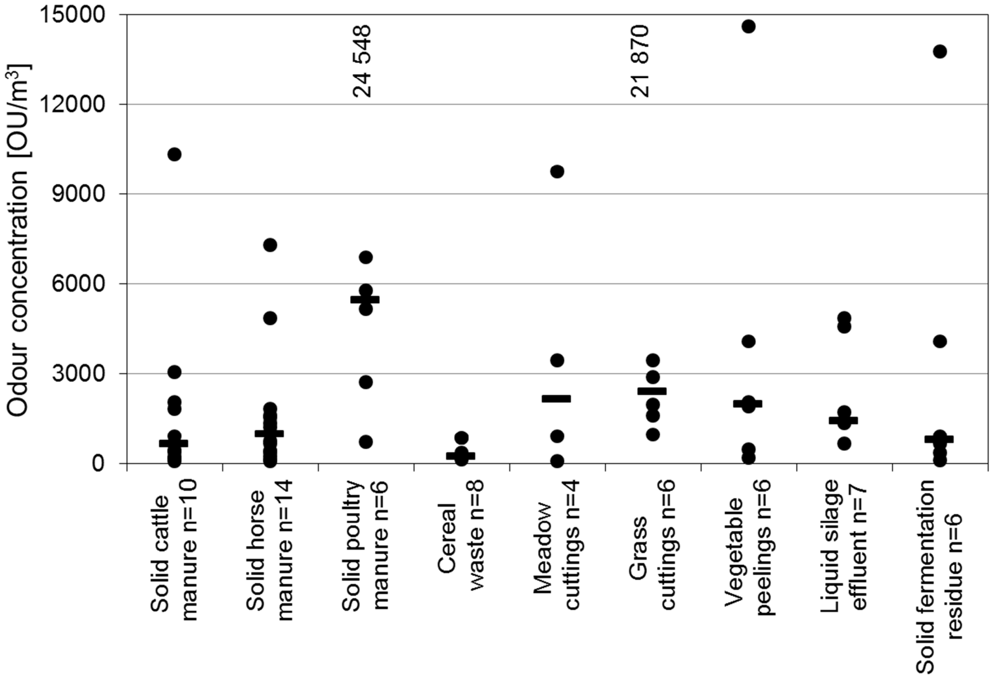

Figure 2: Odour concentration in odour units per m³ [OU/m³] of the different substrates, liquid silage effluent and solid fermentation residues, as single values (●), aggregated as median (–) and number of samples (n).

The odour concentrations of the biogas samples were considerably above the majority of the odour concentrations of the substrates. The values ranged between 30 000 OU/m^3 and reached maximum values of 250 000 OU/m^3.
The odour concentration of biogas of the present study was comparable with data from Brun and Völlmecke (2008), whereas values from Liebich (2004) were even higher (500 000 OU/m^3).

4. Conclusions

With reference to odour reduction, it is important to start with high-intensity odour area sources. Thereby, emitting surfaces must be kept to a minimum as regards duration of storage of substrates. Protection against the sun, wind and precipitation should be provided by means of housing and covering. Surfaces with liquid silage effluent should be avoided and any such drained off quickly via an incline taking a short route. Fresh surfaces should be kept small and movements of material minimised. If need be, in cases of high-intensity odour substrates, mixing or covering with less odour-intensive substrates is to be recommended. The escape of biogas must be prevented by ensuring adequate storage volume, process optimisation, maintenance, regular control and a redundant gas recycling facility. Concerning the required distances to residential areas, an overall consideration of biogas facility and animal husbandry is essential in relation to odour impact.

5. Acknowledgements

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