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Odour Measurements at Different Methanisation Sites

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The number of methanisation production sites increase in Europe. However, the installation of a new site sometimes creates problems with the neighborhood of the sites. The main concern is odours. To respond to these fears, the odour levels emitted by 3 biogas production plants were measured. In order to study the methanisation diversity, different waste treatment plants have been monitored. The waste came from farming (manure, slurry), WWTP sludge, or agro-food were compared. For each plant, 5 sources were investigated. A one year survey indicates that odour emissions changed according to the season. For each site, the main potential odour annoyance impact comes from the input preparation area.

1. Introduction

The increasing concentration of greenhouse gases in the atmosphere, in relation to global energy demand, is leading to a change in the way we produce energy. Biogas production is currently supported by governments of developed countries. Indeed, methanisation is an ecological alternative to the use of fossil fuels. It allows both the treatment of organic wastes and a double recovery level. The treatment of organic waste provides both a digestate and a combustible gas fraction called biogas. Digestate is an improved fertilizer that can be used by spreading or composting. Biogas can be used to produce heat or electricity. In France, energy production in this sector of activity is expected to increase from 1,478 GWh in 2005 to 13,701 GWh in 2020 (Club Biogaz ATEE, 2011).

Unfortunately, the installation of new methanisation units is often refused by the neighbourhood residents. They are afraid of unpleasant odours that they associate, often erroneously, with a health risk. Biogas is mainly composed of 50 to 70% methane and 30 to 50% carbon dioxide, depending on the substrate. While these two compounds are predominant and odourless, several odourous compounds are also generated during anaerobic biotransformation (ammonia, hydrogen sulphide, mercaptans, etc.). Some of them have a very low odour detection threshold and are therefore likely to cause very unpleasant odours, even at very low concentrations in the atmosphere.

This odour annoyance is considered to be the main negative environmental impact of biogas production. Surprisingly, few diagnoses have been carried out on these installations and odour measurements on the entire biogas production chain are very little documented. Some studies have focused on the influence of the operating parameters during the anaerobic digestion on odour impact (Orzi *et al*, 2010, Wilson *et al*, 2006) or on anaerobically stabilized sludge (Tepe *et al*, 2008, Verma *et al*, 2006). In the literature, odour is generally assessed by potential odour concentrations determination *via* sulphur compounds measurement (Wilson *et al*, 2006, Tepe *et al*, 2008, Verma *et al*, 2006).

In this context, the EMAMET project was realised to provide data on atmospheric emissions from these processes (Bayle *et al*, 2016). In this study, odour emissions from three methanisation plants using different substrates have been monitored. Two odour characteristics were evaluated: odour concentrations according to NF EN 13725 and acceptability level according to Olentica method, (Chaignaud *et al*, 2014). To further interpret the results, the annoyance potential (Van Harreveld, 2001) has been calculated from this data to

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determine the odour impact. This parameter allows to prioritize the sources of olfactory annoyance on the biogas production chain.

2. Materials and Methods

2.1 Plant description and sampling locations

The study was performed at three methanisation sites located in France. The three kinds of installations audited in this study received different types of waste (Table 1): site Farm received agricultural waste (manure, slurry), site WWTP received municipal wastewater sludge and for Territory site a mixture of manure and agri-food waste is treated. Moreover, their biogas production was stable. A one-year monitoring including four sampling campaigns was carried out at the WWTP site. Odours were monitored during a sampling campaign in the Farm and the territory production sites during two consecutive days in the spring.

Table 1: Characteristics of the biogas plants

Site	Waste	Biogas production (m^3)
Farm	Manure, slurry	691,708
WWTP	Wastewater sludge	1,559,000
Territory	Manure, slurry, agri-food wastes	6,052,000

There is great variability in the implementation of processes. The way in which inputs are stored, the digestate... However, a general scheme including 5 points is distinguished and makes it possible to locate the sampling sites:

1 / The storage area for raw materials
2 / The raw material preparation area
3 / The digestion reactor
4 / The phase separation zone of the digestate
5 / The digestion tank (liquid and solid)

Sampling plan have been adapted according to the constraints of each site (a breakdown, a lack of access etc..). This study is limited to the characterization of odours on biogas production unit, the spreading of the digestate is not concerned despite its significant impact.

2.2 Odour sampling

The methodology and techniques used for sampling and olfactometric analyses are defined in the European standard NF13725. Gas samples were collected in laboratory-made 40 L Nalophan® bags. Sampling on passive area sources (solid raw materials, digestion tank) was performed using a flux chamber (Odoflux®) positioned over the emitting surface. Air samples are then collected in the outlet duct by means of a pump, which creates vacuum in a case in which the sampling bag is inserted, thereby sucking air into the bag. Samples were transported the same day, the analysis were performed within 30 hours after sampling.

2.3 Odour level characterisation

Olfactometric analyses were carried out according to EN 13725 standards. An olfactometer model ODILE by Odotech Inc was used. This method uses human nose a sensor. Six panelists were employed during test. The results were expressed as odour concentration value (OU_E /Nm^3).
The emitted odour flow rates, expressed in odour units per second (OU_E/s) have been calculated. For area sources where a measurable outward air flow is present, the air flow rate (m^3/h) has been measured with ultrasonic anemometers. For passive area sources, e.g. input storage area, the emitted odour flow rate has been estimated by using a flux chamber.

2.4 Annoyance potential assessment

This method has been previously described (Chaignaud et al, 2014). It is based on assessment of the odour acceptability at four levels of dilution. The lowest one corresponds to the level where all panel members perceive the odour (average threshold). The three other ones correspond to higher odour concentrations. At each dilution level, acceptability is evaluated on a closed scale ranging from -5 to +5 (-5 = very unpleasant odour, 0 = neutral odour, 5 = very pleasant odour). The median acceptability levels are plotted against dilutions levels. The extrapolation of the regression line to no dilution provides the acceptability level for the test sample on an open scale ranging from - ∞ to + ∞.

From acceptability level, the annoyance potential of a specific odour is determined by the following equation:

$$P_A = [Odour] * A$$

Where [Odour] corresponds to odour concentration value expressed in OU_E /Nm^3 and A to the acceptability.

3. Results and discussion

3.1 A one-year odour monitoring at the WWTP biogas production site

To evaluate the variation of the odour concentrations, a one-year follow-up including quarterly measurement campaigns was carried out (Table 1). The survey has been realized on digestion plant from WWTP sludge, because the nature and quantity of waste treated was stable over time.

Table 1: Odour concentrations measured on the biogas plant feed by WWTP sludge in function of season (UO_E/Nm^3)

	Summer	Autunm	Winter	Spring
Input storage area	2,097	1,650	560	2,252
Input preparation area	641	25	30	1,446
Digestion reactor 1	550	370	40	2,244
Digestion reactor 2	175	30	40	1,460
Phase separation zone	580	340	255	1,210

Odour concentrations vary with each season. The lowest concentrations are measured during the coldest period, in winter. The highest one is obtained in spring then in summer. The summer samples were taken on 2016 July 27th for spring on 2017 May 23th, the maximum temperatures recorded on these days were very close to 26.4°C against 25.1°C respectively (http://www.infoclimat.fr). The odour differences are probably due to process variations. No rain was recorded on the 3 days before the samples were taken.
Throughout the year, the highest concentration is always measured in the inputs storage area. The second area with high concentrations is variable. This can be either the inputs preparation area for the summer or digestion reactor 1 for the autumn and spring corresponding to the biogas reinjection room to ensure mixing in the digestion reactor or the phase separation zone in winter. The variation in emission points may depend on the activity present during the sampling. For example, in the input preparation area, the organic matter is sometimes sieved resulting in a discontinuous release of organic waste.

3.2 Odours measurements at different methanisation sites

Eight sampling campaigns have been realized on 3 different sites: 4 for WWTP site, 2 for Territory and Farm sites. Odour concentrations are variable between 25 to 19,000 OU_E /Nm^3 (Table 2).

Table 2: Maximum and minimum odour concentration levels measured on three methanisation plants.

Odour concentration (OU_E /Nm^3)	Farm		WWTP		Territory	
	Lowest	Higher	Lowest	Higher	Lowest	Higher
Input storage area	389	620	560	1250	2,525	7,741
Input preparation area			30	1,446	3,700	19,000
Digestion reactor area	<25	25	40	2,244		
Phase separation zone			255	1,210		
Liquid digestate storage area	2,200	5,650			310	620
Solid digestate storage area	140	320			730	1,100

Except for this last case, the results are not high compared to other activities involving transformations of organic matter. On WWTP site, the odour concentrations variation is more limited; the highest concentration level reached 2,252 OU_E /Nm^3. The highest level recorded is 7,750 OU_E /Nm^3 for the Farm site and 19,000 OU_E /Nm^3 for Territory site.
Higher results of WWTP site are consistent compared to the other sites. The results show different odour levels depending on the biogas production site. The areas with the highest concentrations are the inputs storage area for Farm and WWTP and the inputs preparation area for Territory, the second differs for each site, so respectively the liquid digestate storage area for Farm, the digestor reactor area for WWTP and the inputs preparation area for Territory. The emission points depend on the site construction. For WWTP, the

reactor-related emission occurs at a trapdoor on the reactor roof. The trapdoor is an access point to the reactor digestate outlet. This trap does not exist at the other sites.
Odour flow rates have been calculated to prioritise the different sources (Figure 1).

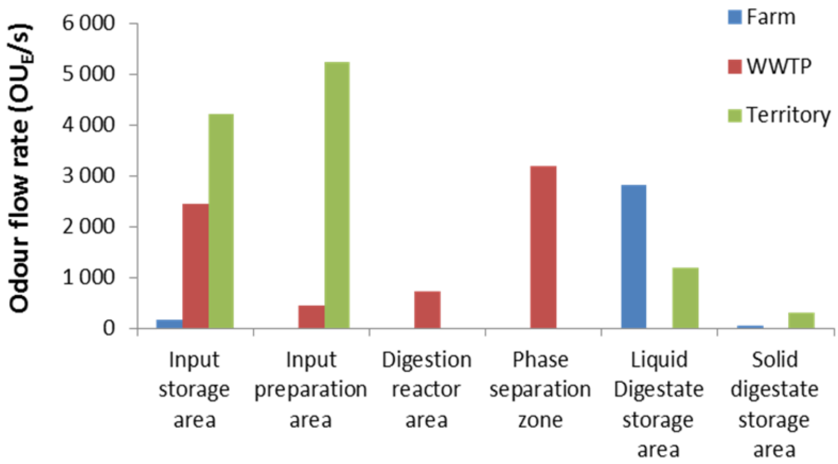

Figure 1: Odour flow rates - biogas plant feed by WWTP sludge in function of season

These values are essential to compare the relevance of different sources. On biogas production plant, any location can lead odour emissions. The digestion reactor and solid digestate storage zones are the least emitting zones. Emission levels from other locations appear to depend on the site. The odour flow rate of the input storage area is related to the biogas production. The main flow rate is reached by the territory methanisation site, the lowest by the Farm site.

3.3 Assessment of odour acceptability and annoyance potential

To further characterize the source with the most negative impact on the neighborhood, the acceptability level of each sample was determined. The results are shown in the Table 3.

Table 3: Acceptability levels

	Farm		WWTP		Territory	
	Lowest	Highest	Lowest	Highest	Lowest	Highest
Input storage area	-7.3	-8.4	-	-11.1	-5	-13.6
Input preparation area			-	-10.3	-9	-10.9
Digestion reactor area	-	-	-	-9.6		
Phase separation zone			-	-10		
Liquid digestate storage area	-8.5	-10			-	-5.2
Solid digestate storage area	-5.7	-7			-	-7.8

The acceptability levels of the odour measured at the three facilities range from -5 to -13.6, highlighting the unpleasant characteristic of the odours. The variability in the acceptability values for the inputs storage area for the territory site (-5 to -13.6), as well as on the different locations of the territory site, can be attributed to fluctuations in activity at each of the sites. The values for the WWTP are more homogeneous.
The relationship between odour concentration levels and acceptability of the different samples was examined. Odour concentrations values have been plotted against acceptability levels (data not shown). Values obtained for seven samples are presented in table 4. No relation is highlighted between the two parameters. Two samples with the same odour concentration can have different acceptability levels (sample 3-4) whereas two samples with different odour concentrations can have a similar level of acceptability (sample 1 and 6). Odours with the highest levels of concentration are not necessarily the most unpleasant. Therefore independent interpretation of these two parameters seems irrelevant. That is why the determination of the potential annoyance is important to determine the sources that may cause inconvenience to the neighborhood (Table 4). Sample 7 with the highest odour concentration is however the most acceptable. It leads to a level of

potential discomfort equivalent to that generated by an effluent that is half as concentrated in odour but less acceptable (sample 5).

Table 4: Potentials of annoyance

	[Odour] (OU_E/m^3)	Acceptability	Annoyance Potential
1	1,210	-10	-12,100
2	2,097	-11.1	-23,214
3	2,200	-8.5	-18,700
4	2,252	-10.4	-23,421
5	3,700	-9	-33,300
6	5,650	-10	-56,500
7	8,000	-4.5	-36,000

The annoyance potential values (Figure 2) clearly show that odour impact differs in function of the site location. The most important impact is linked storage and preparation of waste. The liquid digestate storage can lead to annoyance notably on Farm sector. The territory methanisation site induces the main odour impact. The site set up in WWTP has the lowest impact with the second biogas production. So the impact seems not be related to the amount of biogas produced the WWTP site present. However, this sector has long been confronted with odour management (Lebrero et al, 2011). On this site production, the input storage is carried out inside a building. In addition, the site does not have any exterior storage of solid or liquid digestate. The liquid digestate is returned to the head of the treatment plant and the solid digestate is stored in silos. These storage methods limit the emission of odourous compounds.

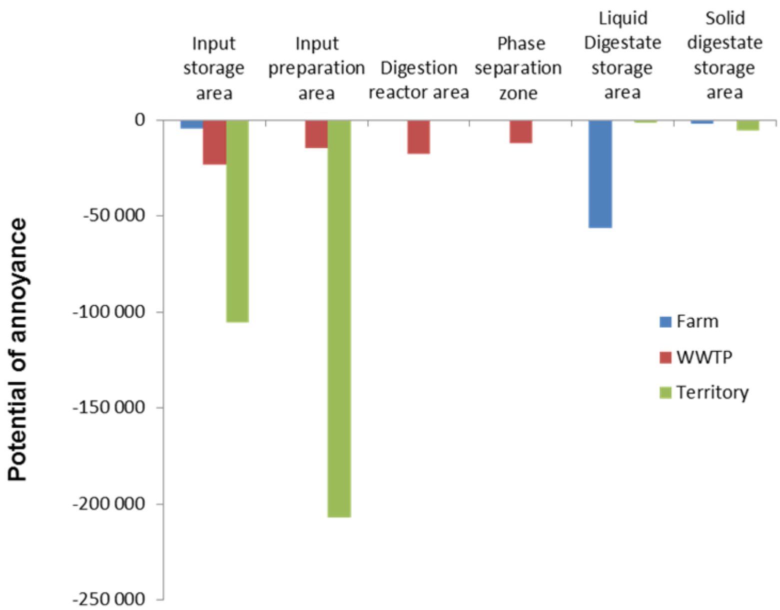

Figure 2: Annoyance Potential of a specific odour from the methanisation sites

4. Conclusions

To our knowledge, this is the first study focused on odour concentration and acceptability levels of waste gases from biogas plants. Overall, the odour concentration level is linked to the plant. Odour concentrations are not very consistent for territory and farm sites. Odours characteristics (concentration, acceptability) at the WWTP plant are less variable than at other sites and relatively low. The one year-survey has highlighted the effect of seasonality (odour concentrations more important at the time of the increase in temperature).

The measurement of the acceptability level of waste gases has highlighted the unpleasant character of the odours. Moreover, the inputs storage areas in every site present a high odour concentration and a weak acceptability that leads to a high potential of annoyance.
Determination of the odour flow rate and the annoyance potential of a specific odour made it possible to show that out of the three sites studied the territory site has the greatest potential impact on the neighbourhood.

Acknowledgments

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