Bioresource Technology 217 (2016) 257–264

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

Analysis of operational methane emissions from pressure relief valves from biogas storages of biogas plants

Torsten Reinelt [a,*], Jan Liebetrau [a], Michael Nelles [a,b]

[a] Deutsches Biomasseforschungszentrum gemeinnützige GmbH, Torgauer Straße 116, 04347 Leipzig, Germany
[b] University of Rostock, Justus-von-Liebig-Weg 6, 18059 Rostock, Germany

HIGHLIGHTS

- Explosion-proof sensors can register triggering events from PRV.
- The used sensors provide the released methane emission and the duration of triggering.
- Methane emissions from PRV depend essentially on operational state.
- The emissions depend essentially on the availability of an automatic operated flare.
- Methane emissions from PRV also depend on atmospheric conditions.

ARTICLE INFO

Article history:
Received 4 December 2015
Received in revised form 15 February 2016
Accepted 19 February 2016
Available online 26 February 2016

Keywords:
Pressure relief valves
Time-variant emissions
Biogas plants
Operational state

ABSTRACT

The study presents the development of a method for the long term monitoring of methane emissions from pressure relief valves (PRV[1]) of biogas storages, which has been verified during test series at two PRVs of two agricultural biogas plants located in Germany. The determined methane emission factors are 0.12 g CH_4 kWh_{el}^{-1} (0.06% CH_4-loss, within 106 days, 161 triggering events, winter season) from biogas plant A and 6.80/7.44 g CH_4 kWh_{el}^{-1} (3.60/3.88% CH_4-loss, within 66 days, 452 triggering events, summer season) from biogas plant B. Besides the operational state of the biogas plant (e.g. malfunction of the combined heat and power unit), the mode of operation of the biogas flare, which can be manually or automatically operated as well as the atmospheric conditions (e.g. drop of the atmospheric pressure) can also affect the biogas emission from PRVs.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

In Germany a number of about 8,000 operating biogas plants supplying about 25,000 kWh_{el} per year is present at the end of 2014 (IEA Bioenergy Task 37, 2015). One main target of production and use of biogas is the reduction of greenhouse gases (GHG) in the energy sector, whose efficiency is evaluated by life cycle assessments. However, so far methane emissions from biogas plants have been based on assumptions. An often used value is 1% methane loss related to the overall methane production rate from the whole gas-producing plant (Daniel-Gromke et al., 2015), which includes amongst others leakages on biogas-bearing plant components (e.g. gaps in the biogas storage foils) and operational methane emissions from PRVs. In particular the operational methane emissions from PRVs represent a great uncertainty within this default value, because nobody has ever determined the specific methane emission rates from PRVs in contrast to other major emission sources like digestate storages (Daniel-Gromke et al., 2015; Liebetrau et al., 2013). Most methane emission sources from biogas plants, i.e. leakages, diffuse emissions from digestate storage tanks or the methane slip in the off-gas from combined heat and power (CHP) units, were already intensely investigated (Clemens et al., 2014; Gioelli et al., 2011; Holmgren et al., 2015; Liebetrau et al., 2013; Li et al., 2013; Sneath et al., 2006; Van Dijk, 2012). Also the overall methane emissions from biogas plants were investigated by means of remote sensing methods (Flesch et al., 2011; Groth et al., 2015; Hrad et al., 2015; Mønster et al., 2014). These emission measurements can describe only a limited period of time. Consequently the transfer of the determined emission factors to longer time periods or general operation of the plant has to be done with care and proves to be difficult. In particular operation-related and time-variant methane emissions from PRVs have a behavior difficult to be foreseen and require a measurement method which allows long-term monitoring of the released

* Corresponding author. Tel.: +49 341 2434 374; fax: +49 341 2434 133.
E-mail address: torsten.reinelt@dbfz.de (T. Reinelt).
[1] PRV: pressure relief valve.

http://dx.doi.org/10.1016/j.biortech.2016.02.073
0960-8524/© 2016 Elsevier Ltd. All rights reserved.

Table 1
Review of methane emission measurement methods used on biogas plants.

Emission source	Measurement method	Literature
Biogas utilization (methane slip in off-gas of CHP or upgrading unit)	Direct analysis of methane concentration and volume flow in exhaust pipe with standardized methods	Liebetrau et al. (2013), Van Dijk (2012)
Localization of leakages on biogas-bearing plant components	Biogas plant survey by using methane sensitive detection systems (e.g. IR camera, portable methane lasers or hand held methane detectors)	Clemens et al. (2014), Holmgren et al. (2015), Liebetrau et al. (2013)
Quantification of leakages on biogas-bearing plant components	Dynamic chamber method: encapsulation of the leakage by a dynamic chamber and determination of methane concentration and volume flow with standardized methods	Liebetrau et al. (2013), Holmgren et al. (2015)
Open digestate storages	Static/dynamic chamber method: touchdown of static or dynamic chambers on the digestate surface and determination of a surface specific emission rate used for extrapolation to the whole surface area	Gioelli et al. (2011), Holmgren et al. (2015), Liebetrau et al. (2013)
Not gastight sealed digestate storages	Air injection method: supply of fresh air into the headspace of the storage and measurement of the decrease of the methane concentration by standardized methods	Liebetrau et al. (2013), Sneath et al. (2006)
Overall biogas plant	Inverse dispersion modeling method: analysis of methane concentration windward and downwind to the plant by open path lasers and analysis of the weather conditions; simulation of the emission rate by using the measured data and a Backward Lagrangian stochastic model	Flesch et al. (2011), Groth et al. (2015), Hrad et al. (2015)
Overall biogas plant	Tracer dispersion method: combination of a controlled release of tracer gas from the biogas plant with concentration measurements downwind of the plant by using a cavity ring down spectrometer	Holmgren et al. (2015), Mønster et al. (2014)
Operational emissions from PRVs	Counting of single triggering events by an explosion-proof photo sensor installed in the exhaust pipe (no quantification of the emitted methane volume flow)	(Lehner et al., 2010)
Operational emissions from PRVs	Determination of the emitted methane volume by an explosion-proof flow velocity sensor installed in the exhaust pipe	Presented study

methane volume, the frequency of the release events and the operational states causing the emissions. For classification of the presented method, Table 1 gives a brief review about emission measurement methods applied at biogas plants.

Since the global warming potential of methane has been set to a value of 28/34 (Myhre et al., 2013), a better knowledge of operational methane emissions and related specific emission factors becomes more important because methane is the dominant GHG from the biogas technology. Due to the lack of sufficient monitoring equipment there is no reliable data, yet.

Looking at the technical background, each gastight tank or biogas storage has to be equipped with at least one PRV for positive and negative pressure each to avoid pressure conditions exceeding the design parameters leading to severe damages on the biogas storage facilities. For full scale plants different principals for PRV are in use. There are hydraulic (surge tank), hydraulic weighted (water seal) and mechanical PRV systems. However, independent from the used system, a PRV usually has an exhaust pipe (~1–5 m length) which is used to release the biogas into the atmosphere. In any case a PRV is a safety device which should not be in operation under normal process conditions in particular since any relief event also results in the emission of raw biogas leading to negative ecological effects. However, the occurrence of triggering events mainly depends on the design of the biogas storage management, i.e. the relation between the availability of a secondary gas utilization (biogas flare) and its mode of operation (automatically or manually operated), the operation of the biogas storages (filling level in normal operation), the operational state of the plant (e.g. shut down of the primary gas utilization) and the atmospheric conditions (e.g. air pressure changes, ambient temperature changes). Additionally these influences can interact and enforce its impact on the triggering of PRVs. In Germany the use of one and two layer low pressure foil gas storages on top of a digester is the most common gas storage. Assuming a high filling level of such a biogas storage (e.g. 90%) during normal operation, the remaining capacity of the storage disallow any quick changes on the gas volume e.g. caused by an unexpected shutdown of the gas utilization. At filling levels near the limit a triggering of the PRVs can be already caused by small deviances from the normal operation or even changes in the atmospheric conditions as temperature rise and atmospheric pressure changes.

In general the methane emissions from PRVs firstly depend on the operational state. A typical malfunction causing triggering events from a PRV is the outage of the primary gas utilization, since the produced gas is not converted any more. This kind of triggering event should be normally avoided by automatically operated secondary gas utilization as a flare. However, the functionality of a stationary flare highly depends on the integration into the biogas storage operation and the gas transportation management. Only an automatic operated flare regulated by the operating pressure of the gas storage or the filling level of the biogas storage can safely avoid emissions from PRV caused by unexpected operational conditions.

So far the PRVs of five biogas plants in Germany were monitored by simply counting the frequency of triggering events (Lehner et al., 2010). At three plants triggering events of the PRVs did occur during the measurement periods lasting 297 up to 484 days. At two of them the PRVs have been occasionally activated during 3–6 days, at the third more frequently during 70 days. However, this data does not provide a quantification of the methane emission flow rate, but only the number of triggering events. Going further, the method presented here aims at a determination of the operation-related methane emission mass flow rates by a long-term monitoring and consequently a reliable emission factor from the investigated PRVs.

2. Methods

2.1. Plant description

The two investigated plants were different regarding their size and their process technology influencing operational methane emissions. Both plants were based on wet fermentation technology and a mesophilic temperature level. Plant A had an installed electrical capacity of 1875 kW_{el} (3 × 625 kW_{el}) and two digestion lines including a main and post digester and a gastight digestate storage each. An additional open digestate storage followed after the gastight ones. As input material pig slurry and energy crops were used. The installed PRVs were based on a hydraulic system (cp. Section 2.2). First the PRV from the post digester (700 m^3 biogas capacity, 2 installed PRV, 2.2 hPa opening pressure) and then from

Download English Version:

https://daneshyari.com/en/article/679167

Download Persian Version:

https://daneshyari.com/article/679167

Daneshyari.com