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Impact of Meteorological Parameters on Extracted Methane Concentration at Landfills

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1. Introduction

Landfill gas (LFG) consists of methane (CH_4: 55-60 % v/v) and carbon dioxide (CO_2: 40-45 % v/v). CH_4 is 28 times more powerful than CO_2 in terms of global warming potential (IPCC, 2013). Landfills are one of the main anthropogenic sources of methane emission to atmosphere (Xu et al. 2014), and these emissions can continue for several decades (Scheutz et al. 2009).

If LFG emissions are not mitigated or controlled, they can result in other negative effects apart from global warming such as explosion or fire hazard, odour, and vegetation damage (Christophersen et al. 2001). Produced methane in landfills can be extracted and used as a renewable energy source to produce heat and electricity. Therefore, it is crucial to understand the factors that can affect methane extraction from landfills.

The objective of this study was to evaluate the impact of meteorological parameters (barometric pressure, relative humidity, wind speed, and ambient temperature) on extracted methane concentrations that enter the gas engine for electricity production. The outcome of this study can help the landfill operators to optimize extraction facilities according to changes in meteorological parameters in order to achieve lower emissions and higher recovery of methane, which is beneficial both environmentally and economically.

2. Material and Methods

This study was done on Odense Nord and Stige Ø landfills, which are located north of Odense, Denmark next to Odense Canal. Stige Ø Landfill was established in 1964 and received several of the waste types generated in the Odense area including municipal solid waste until the closure in 1996. The landfill contains around 10 million tons of mixed waste and covers an area of 54 hectares. The Odense Nord landfill received waste from 1994, and it is still in operation. Odense Nord receives approximately 400,000 of mixed waste, shredder waste, asbestos, polluted soil, garden waste and sludge per year. In the northern part of the site, composting of park and garden waste and sludge mixed with straw is carried out.

Gas extraction facilities are installed in Stige Ø and three cells of Odense Nord (1a, 1b, and 1c), which contain mixed waste. Cells 1a and 1a are finalized, and they have vertical gas extraction wells installed. Cell 1c is still receiving mixed waste and it has a horizontal gas extraction system in place. The finalized cells are covered with 70 cm of permeable soil and 30 cm of compost on top of that. Cells in operation are temporarily capped with 20 cm of soil. A map of Odense Nord landfill with its different sections is presented in Figure 1.

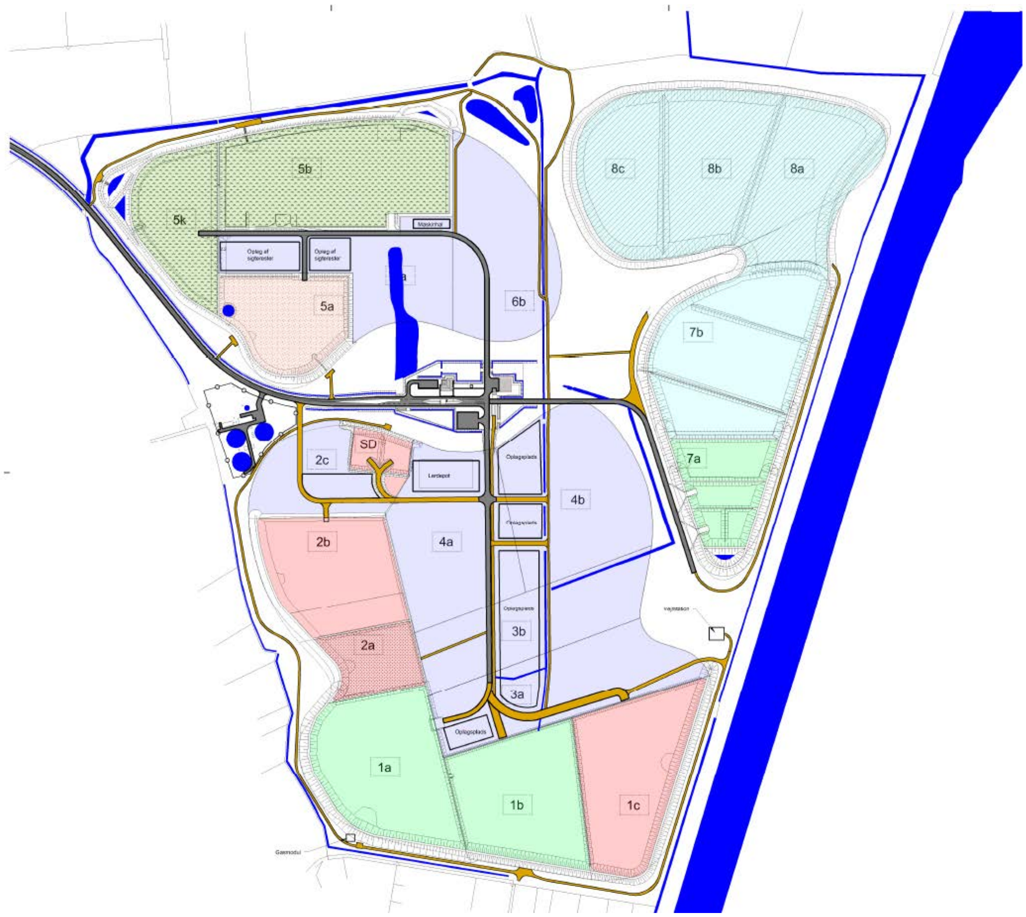

Figure 1. Map of Odense Nord landfill showing the outline of the different waste cells.

There are four measuring, pump and regulation modules (MPR-module) in Stige Ø and one MPR-module in Odense Nord landfill. These five modules are connected to a local power plant where there is a gas engine producing electricity and a boiler producing heat. At both the Stige Ø and Odense Nord sites the gas composition and meteorological data are registered and stored.

The time period of one month from 01.01.2015-31.01.2015 was selected as there were significant fluctuations in meteorological parameters in this time period, which made it more interesting to be studied. Barometric pressure, relative humidity, wind speed, ambient temperature, and precipitation were the selected meteorological parameters. Precipitation was not studied as it was not fluctuating significantly during the selected time period. The collected meteorological data were hourly average, recorded at on-site weather station.

The methane concentration (vol. %) of the LFG that enters to gas engine was selected to be studied as it was the average methane concentration of all of the extraction wells, representative for the whole area of the both landfills. Methane concentrations were recorded every two minutes, which then were converted to hourly averages to be used for linear regression.

3. Results and Discussion

Methane concentrations entering the gas engine were studied as a function of barometric pressure, relative humidity, wind speed, and ambient temperature in order to investigate if these were correlated. The correlation factors (R^2 values) at the 95 % confidence level are presented in Table 1. R^2 values were used to show the relation between two variables. R^2 value of 1 shows a perfect correlation between the two variables whereas a value of 0 shows that there is no correlation between two variables (James et al. 2013).

Table 1. R^2 values obtained from correlation plots

	Barometric pressure	Relative humidity	Wind speed	Ambient temperature
Methane concentration	0.4888	0.0006	0.1213	0.0609

Methane concentrations showed very low correlation factor with relative humidity, wind speed, and ambient temperature. The only meteorological parameter that showed quiet high R^2 value with methane concentrations was the absolute barometric pressure (R^2 value of 0.4888). Apart from the R^2 values, the significant correlation between two variables should be seen visually in a scatterplot. In this regard, methane concentrations were plotted as a function of the barometric pressure (Figure 2).

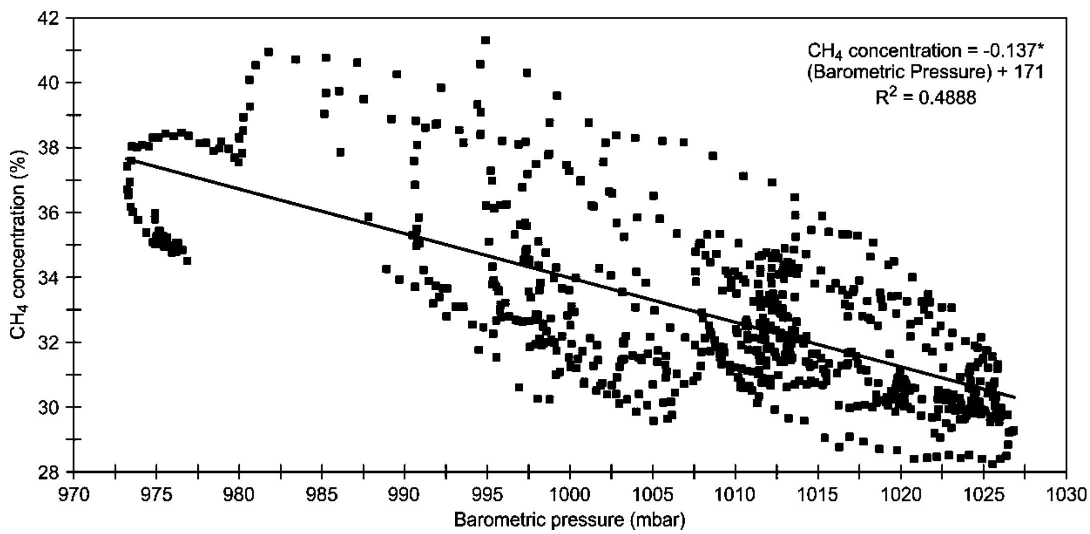

Figure 2. Methane concentration as a function of barometric pressure.

As it can be seen from Figure 2, higher barometric pressure results in lower methane concentration. The reason could be that with higher barometric pressure, more atmospheric air flows into the landfill body and dilutes the landfill gas thus methane concentration decreases.

Czepiel et al. (2003) found a negative correlation between methane emissions and barometric pressure by whole-site field measurement. Modeling studies (Latham & Young 1993, and Nastev et al. 2001) have also concluded a negative correlation between barometric pressure and methane emissions at landfills.

Another objective of this study was to investigate if changes in barometric pressure have an impact on the observed methane concentration. In order to achieve this objective, the period of January 2015 was divided to periods of falling or rising barometric pressure. In total, 32 periods were obtained (Figure 3).

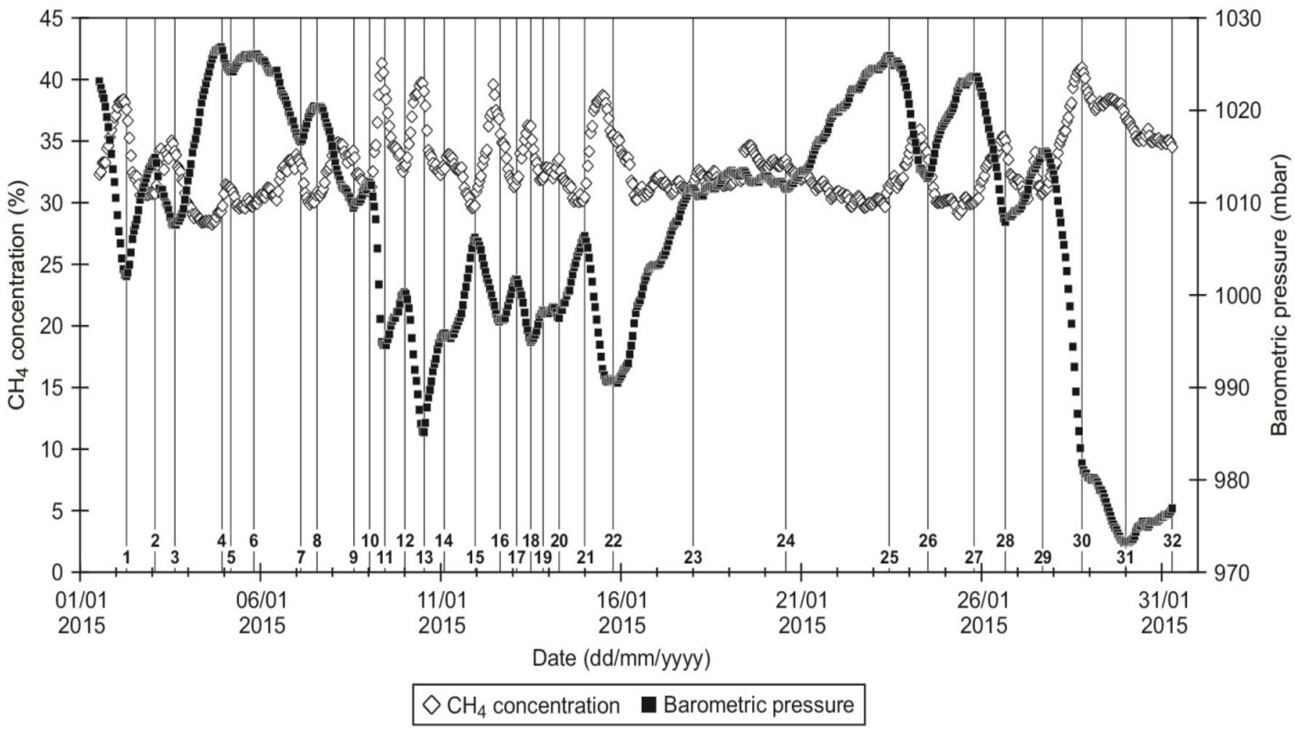

Figure 3. CH_4 concentration and barometric pressure as a function of time. The data series is divided into 32 sections according to rising or falling barometric pressure

R^2 values were calculated for individual periods of rising or falling pressure. The resulted R^2 values for periods of falling and rising pressure are shown in Table 2 and Table 3, respectively. Periods of 20 and 24 were not considered in the results as barometric pressure was fluctuating too much to allocate them to either rising or falling barometric pressure.

Table 2. R^2 values for periods of falling barometric pressure

Number of zone	**R^2**	**Number of zone**	**R^2**	**Number of zone**	**R^2**	**Number of zone**	**R^2**
1	0.91	9	0.90	18	0.92	30	0.94
3	0.82	11	0.97	22	0.79	31	0.22
5	0.87	13	0.88	26	0.94		
7	0.91	16	0.84	28	0.91		
Average	0.84						

Table 3. R^2 values for periods of rising barometric pressure

Number of zone	**R^2**	**Number of zone**	**R^2**	**Number of zone**	**R^2**	**Number of zone**	**R^2**
2	0.83	10	0.78	17	0.91	25	0.92
4	0.78	12	0.92	19	0.91	27	0.76
6	0.76	14	0.79	21	0.83	29	0.45
8	0.83	15	0.95	23	0.60	32	0.80
Average	0.80						

During the one month period 14 events with a fall in barometric pressure were recorded. Out of the 14 events, 12 showed R^2 values higher than 0.80. Similar 16 periods with a pressure rise were observed from which 8 events showed R^2 values higher than 0.80. The average R^2 value for periods of falling barometric pressure (0.84) was slightly higher than R^2 value for periods of rising barometric pressure (0.80). Overall, it is clear that the pressure changes had a more significant impact on the methane concentration than the absolute pressures. Individual periods thus showed higher R^2 values compared to R^2 values for the whole period of January 2015.

Negative correlation between methane emissions at landfills and barometric pressure changes has been seen in other studies as well. Poulsen et al. (2003) observed higher methane fluxes during periods of rapidly falling atmospheric pressure. Nwachukwu and Anonye (2013) also found that barometric pressure was a controlling factor on methane concentration during periods of falling barometric pressure. However, it was concluded that methane concentration is not controlled by atmospheric pressure during periods of rising barometric pressure.

4. Conclusions

This paper studied the impact of meteorological parameters (relative humidity, wind speed, ambient temperature and barometric pressure) on the methane concentrations entering the gas engine at Odense Nord and Stige Ø landfills. The correlation factor R^2 for linear regression between two variables was used to study the significance of correlation.

Methane concentration data did not show significant correlation with relative humidity, wind speed, and ambient temperature. The only meteorological parameter that showed quiet high correlation factor (R^2 value of 0.4888) with methane concentrations was the absolute barometric pressure. The correlation was also observed visually in a scatter plot. It was observed that a higher barometric pressure, results in a lower methane concentration in the LFG entering the gas engine.

This paper also investigated if changes in barometric pressure have an impact on the observed methane concentration. This was done by dividing the period of one month to shorter periods of rising or falling barometric pressure. Periods of falling barometric pressure showed slightly higher average correlation factor with methane concentrations (R^2 = 0.84) in comparison to periods of rising barometric pressure (R^2 = 0.80). Splitting the data for the whole period of one month into periods of changes in barometric pressure resulted in higher correlation factors. It indicates that the pressure changes had a more significant impact on methane concentration than the absolute pressures.

These results are important for optimization of gas extraction facilities at landfills in order to have higher methane extraction and lower methane emission to atmosphere, thus benefiting both environment and economy of the landfills. Moreover, these results suggest that it is important to take barometric pressure changes into consideration when measuring the landfills gas emissions.

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