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DEVELOPMENT OF AN INNOVATIVE UAV-MOUNTED SCREENING TOOL FOR LANDFILL GAS EMISSIONS

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SUMMARY: Identification of landfill gas emission hot spots are potentially a very time consuming process, and the use of an Unmanned Aerial Vehicle (UAV) based screening tool could be an effective investigation strategy. In this study, the potential use of a long-wave thermal infrared camera was investigated. The correlation between surface soil temperatures and landfill gas emissions was examined in a field study conducted at Hedeland Landfill near Roskilde, Denmark. The surface temperatures were both measured with a soil thermometer and a long-wave infrared camera and compared to detected methane surface concentrations and fluxes. The results showed no clear tendency of correlation between measured surface temperatures and methane surface concentrations. The differences in the surface temperature ranges were limited, hence making it difficult to detect clear anomaly temperatures. A smaller correlation between the representative emission hot spots and the temperature detected at the thermal images taken with the long-wave infrared camera, seems to be present.

1. INTRODUCTION

Construction of cost-efficient systems for landfill gas (LFG) migration cut-off and/or mitigation of greenhouse gas emissions from landfills are depending on knowledge about the location of emission hot spots. To identify areas with significant landfill gas emissions a high spatial resolution is needed as emission patterns often exhibit high spatial and temporal variability (Röwer, et al., 2011; Kjeldsen, et al., 2009). Surfaced-based screening and measurement activities to accommodate the expected spatial/temporal variability can be very time consuming since landfill surfaces are often several hectares. Developments of efficient investigation strategies as well as screening and emission measurement techniques are highly needed to develop conceptual understanding of the governing gas transport and emission processes. Landfill gas can have a temperature of 40-60 ºC and the leaks of landfill gas could potentially be seen as thermal anomalies at the surface of the landfill using an infrared (IR) camera (Desideri, et al., 2007; Lewis, et al. 2003a). An UAV-based IR camera could potentially be a quick technique, which very cost efficiently could delineate emission locations for further investigations.

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2. BACKGROUND AND METHOD

An UAV-based IR camera was tested by overflying landfill surfaces and delineate thermal anomalies. Simultaneously, surface-based measurements were conducted using soil thermometers, in-field measurement of methane and carbon dioxide gas concentrations and methane fluxes were measured using stationary chambers. Detailed campaigns were carried out to gain important experiences in the use of the UAV-based IR camera to evaluate the usefulness of evaluating thermal anomalies for screening spatial and temporal variability in gas emissions.

2.1 Testsite

Hedeland landfill, a closed landfill near Roskilde, Denmark was chosen as test site. Hedeland landfill received around 2 million tons of waste with low organic matter and around 1 million tons of soil in the periode 1979 to 2009.

In order to evaluate the usefulness of the IR camera as a screening tool for LFG emission hot spot location, detailed campaigns needed to be carried out under different meteorological conditions. Surface-based field measurements of concentrations and fluxes of methane and carbon dioxide were compared with the results of the thermal screenings using the IR camera from a stationary position.

For use in the detailed campaigns a 10x10 meter test area with a 1x1 meter grid was established on a slope were landfill gas emissions were verified. The corners in the test area were marked with aluminium plates in order to identify them at the thermal pictures due to their different emissivity.

2.2 Measurements

In total, five measurement campaigns were conducted during spring 2015. In the first four campaigns, conducted during March 2015, soil- and surface temperatures and surface concentrations of methane were measured whereas only the last campaign (May 14^{th}) included emission measurements. In general, measurements were conducted in 81 grid points in the test area. At the same time a thermal picture were taken with a long-wave thermal infrared (TIR) camera from the opposite slope with a distance of approximately 30 meters. The thermal pictures were taken using a TIM 450 TIR camera from Micro Epsilon equipped with a lens which has an aperture angel of 38º. The purpose was to identify the degree of correlation between the release of methane gas into the atmosphere and eventual thermal anomalies detected with both a soil thermometer and a thermal infrared camera.

Methane gas emissions were measured using a Flame Ionization Detector (FID) from Thermo Scientific (a Toxic Vapor Analyser, TVA-1000B) 5 cm above the ground. The temperatures of the soil were measured using a hand held digital thermometer (AH-50A type K from RS Components) measuring 5 cm under ground.

Methane fluxes were measured at three points in the test area with elevated methane concentrations using a flux chamber with the dimensions A = 0.0779 m^2 and V = 0.0182 m^3. Methane concentrations in the flux chamber were detected each 30 seconds for 5 minutes using the FID.

3. RESULTS AND DISCUSSION

The results show a wide variation especially in the measured methane concentrations but also for the soil temperature between the 81 grid points in the test area. The soil temperature measured with the soil thermometer varied up to 2.3 degrees between the point with the highest and the lowest temperature for one of the campaign days (March 18th). Methane concentrations 5 cm above the surface varied between approximately 3 ppm and up to 2000 ppm. None of the four campaigns showed a strong correlation between the measured soil temperatures and the detected methane surface concentrations, see Figure 1.

Methane flux rates were studied in three points with elevated methane surface concentrations. The measured flux varied from 2.13 to 712 g CH_4 m^{-2} d^{-1}, see Figure 2.

Temperature data for the test area were also collected using the thermal infrared camera. Figure 3 shows the thermal images from each of the four measuring campaigns. The 81 measuring grid points in the test area were marked with wooden markers and that is what courses the lighter/warmer stripes on the themal pictures especially on March 18th. The aluminium plates in the corners of the test area are marked with white circles and do not represent the temperature at the edge of the plates. The test area tends to be warmer in the lower right corner at all four campaigns.

There are a small tendency of a correlation with slightly elevated surface temperatures and some points with higher methane concentrations in the lower right corner. However, the lack of anomaly temperatures in the TIR images makes it difficult in the use of detecting gas leakages.

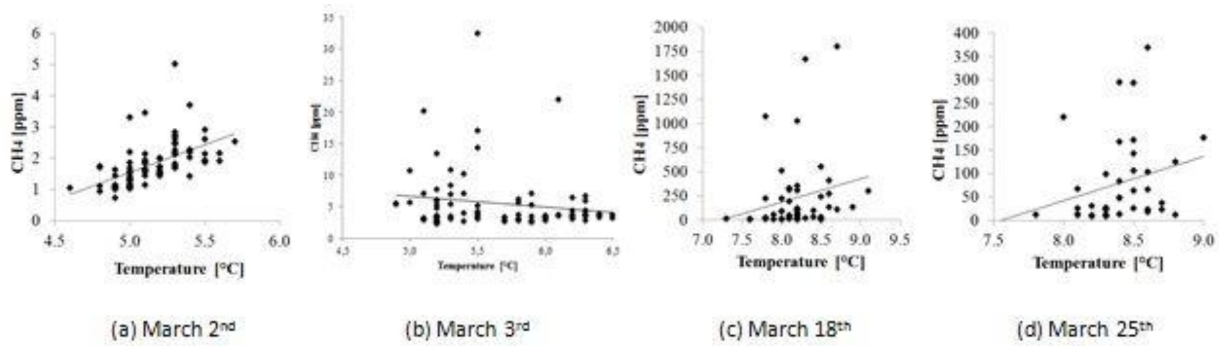

Figure 1. Methane concentration and soil temperature correlation plots from the four measuring campaigns.

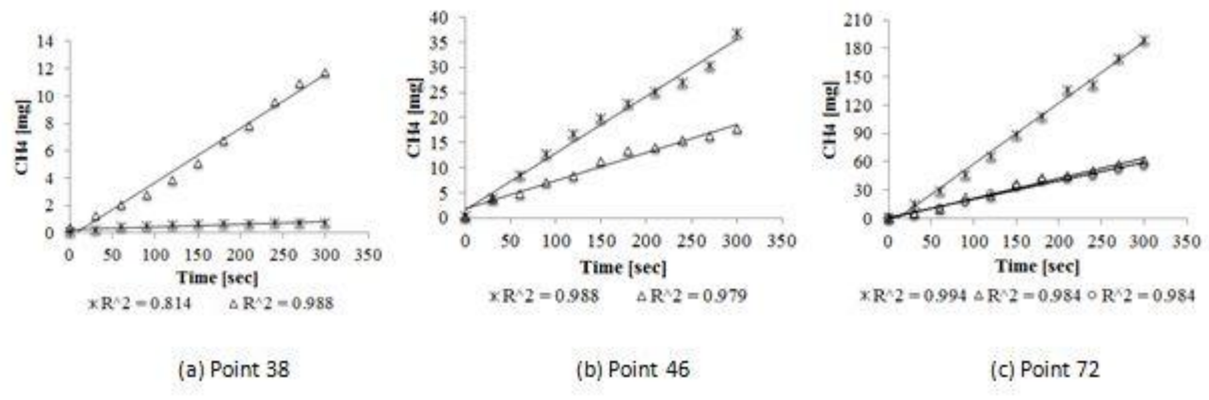

Figure 2. Methane flux rates, May 14th.

No direct correlation could be observed between temperatures from the TIR images and landfill gas concentrations in the study of gas leakage from landfills by Lewis et al. (2003b). The same was concluded by Battaglini et al. (2013), stating that relative thermal anomalies do not necessarily resemble anomalous flux releases.

A comparison of the soil temperature detected with the soil thermometer and the surface temperature detected with the TIR camera are shown in Figure 4. A linear tendency was expected but the measurements showed high variations depending on the day of the campaign. In Lewis et al. (2003b) a good correlations between digital thermometer measurements of the ground surface temperature and the one provided by the TIR camera were found, but the correlation only accounted for the gas leak anomaly sample points with temperatures of 10-40°C.

For this study no high variations in the temperatures were observed, neither for TIR- nor for the digital measurement of soil temperatures. All temperature measurements were <10°C, and thus anomalies in temperature were difficult to identify.

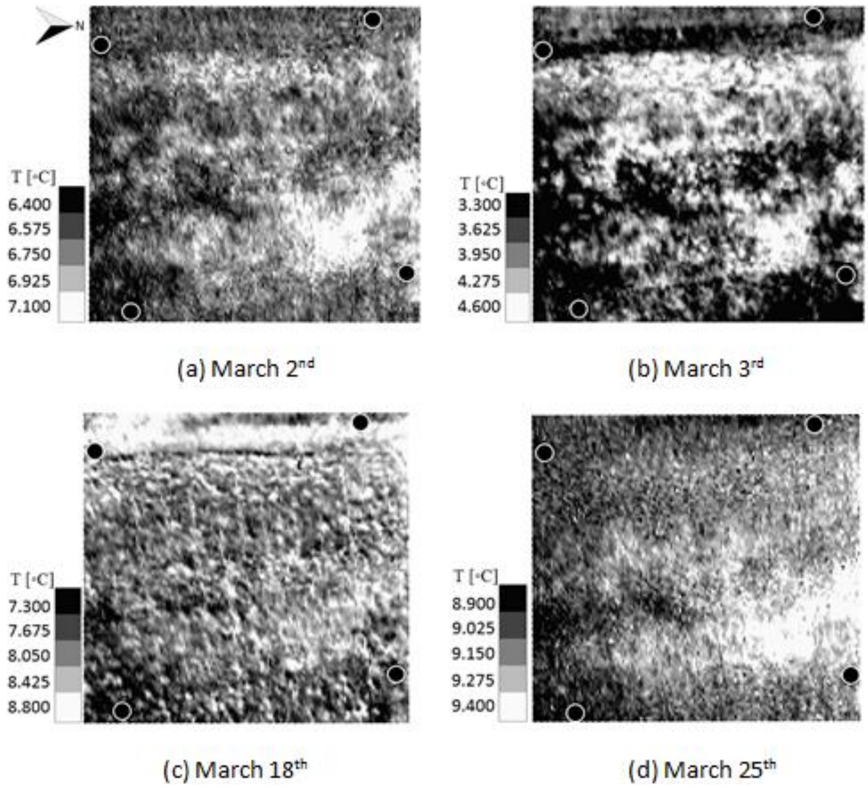

Figure 3. Thermografic images of the test area for all four measurement days.

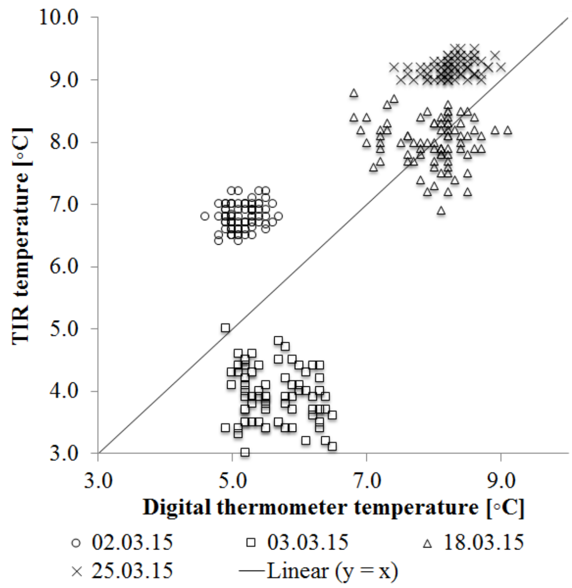

Figure 4. Soil temperatures measured with soil thermometer versus surface temperature registrered with a termal infrared camera.

4. CONCLUSIONS

In this field study the correlation between landfill gas emissions and soil temperatures detected with a soil thermometer and surface temperature detected with a long-wave thermal infrared camera were examined. The results from the measuring campaigns showed no clear tendency of correlation between measured surface and soil temperatures and methane surface concentrations.

A smaller correlation between the representative hot spots and the thermal images seemed to be present at the thermal images taken with a long-wave infrared camera. However, it should be underlined that the differences in the surface temperature ranges were limited, hence making it difficult to detect clear anomaly temperatures.

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