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Fjelsted, Lotte; Scheutz, Charlotte; Christensen, A. G.; Kjeldsen, Peter

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SCREENING TOOL FOR LANDFILL GAS EMISSION HOT SPOTS BASED ON INFRARED IMAGES

L. FJELSTED*, C. SCHEUTZ**, A.G. CHRISTENSEN* AND P. KJELDSEN**

** NIRAS A/S, DK-3450 Allerød, Denmark*
*** Department of Environmental Engineering, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark*

SUMMARY: Identification and delineation of landfill gas (LFG) emission hot spots is a necessary prerequisite to mitigate greenhouse gas emissions from landfills. Ground-based measurement techniques are time consuming to perform as landfills are often several hectares and the LFG emissions show high spatial variability. An Unmanned Aerial Vehical (UAV) equipped with a thermal infrared (TIR) camera could potentially be an efficient screening tool for locating LFG emission hot spots. This study evaluated the ability of a TIR camera to locate LFG emission hot spots. The TIR camera was tested at two Danish landfills with different emission characteristics. The TIR images were compared with ground-based emission measurements conducted with static flux chambers and soil temperatures measured using a soil thermometer. The results showed highly different ranges between the LFG emissions at the two landfills. At the landfill with the lowest LFG emissions it was not possible to see any thermal anomalies in the TIR images whereas, at the landfill with the highest LFG emissions, the TIR images showed higher temperatures in the areas where the highest LFG emissions were measured.

1. INTRODUCTION

Landfill gas (LFG) emissions show high spatial and temporal variability, why a high spatial resolution is needed to discover significant LFG emission hot spots (Röwer, et al., 2011; Kjeldsen, et al., 2009). However, surfaced based screening and emission measurement activities required to accommodate the expected spatial/temporal variability, can be time consuming to perform. Development of efficient screening techniques and tools to deliniate emission hot spots are highly needed as knowledge about the emission hot spot patterns are nessessary to construct cost-efficient LFG mitigation systems. Landfill gas has a temperature of 40° - 60°C and the leaks of landfill gas could potentially be seen as thermal anomalies at the surface of the landfill using a thermal infrared (TIR) camera (Desideri, et al., 2007; Lewis, et al. 2003). An UAV-based (Unmanned Aerial Vehicle) TIR camera could potentially be a quick technique, that cost-efficiently could delineate emission locations for further investigations.

In this project the possibility of using an UAV-mounted TIR camera is evaluated by comparison of TIR images with ground-based measurements of soil surface temperatures, using a soil thermometer, and LFG emissions (methane and carbon dioxide), using static flux chambers. This study is a follow up on the work presented at Sardinia 2015 in Fjelsted et al. (2015). The work has been extended and tests have been conducted at two Danish landfills with different emission characteristics.

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2. BACKGROUND AND METHODS

The ability of an UAV-based TIR camera to delineate LFG emission hot spots at the surface of landfills has been tested at two Danish landfills, Hedeland landfill near Roskilde and Audebo landfill near Holbæk. The TIR images were compared to ground-based measurements of soil temperature and LFG emissions.

2.1 Test sites

Hedeland Landfill is established in an old gravel querry, and received in the period from 1979 to 2009 around 2 million tons of low organic waste and 1 million tons of soil. The landfill has a bottom liner and leachate collection system. Periodic collection of LFG takes place in parts of the landfill.. The landfill is covered with 1 meter of soil in the area where this research took place.

At Audebo Landfill approximately 600,000 tons of mixed waste has been deposited from 1990 to 2009. Today Audebo Landfill receives around 15,000 tons of low carbon waste per year. The landfill has a leachate collection system and a 1 meter thick top cover of soil.

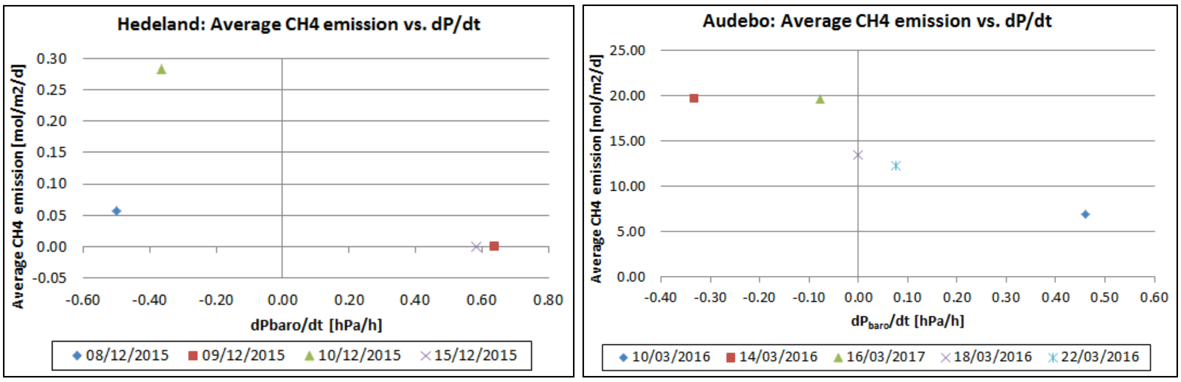
To address the spatial variability in the LFG emissions, a test area of 100 m^2 (10x10 meter) was established at both landfills in parts where earlier surface screenings had shown high LFG emissions. The test areas were devided into a 1x1 meter measuring grids and LFG hot spots were identified and added so there in total was 100 measuring points at each test area.

2.2 Measurements

To address the temporal variation and influence of the atmospheric conditions the measurements were conducted four days at Hedeland Landfill in December 2015 and five days at Audebo Landfill in March 2016. At all nine measurering campaigns, a TIR image was captured from a distance of 25-30 meters early in the morning before sunrise with a TIM 450 TIR camera from Micro Epsilon equipped with a 38° aperture angel lense. Afterwards, LFG emissions were measured in the 100 measuring points using a static flux chamber and a 1312 Photoacoustic Multi-gas Monitor (Innova) from LumaSense. Simultaneously, soil temperatures were measured at the surface and at 5 cm and 10 cm below surface.

3. RESULTS AND DISCUSSION

The LFG emission patterns and magnitude of the emissions were substantially different at the two landfills. At Hedeland landfill the emissions were in general lower compared to the emissions at Audebo and there were only few points with methane emissions. On days with increasing atmospheric pressure no methane emissions were seen at Hedeland, see Figure 1 (a). The average methane emission for the 100 measuring points varied between <0.0031 mol m^{-2} d^{-1} (detection limit given in Scheutz et al. (2011)) and 0.28 mol m^{-2} d^{-1} (4.5 g m^{-2} d^{-1}) with the highest emissions on the days with decreasing barometric pressure (18 mol m^{-2} d^{-1} or 290 g m^{-2} d^{-1}). The results from Hedeland Landfill reported in Fjelsted et al. (2015) showed methane flux rates between 2.13 g m^{-2} d^{-1} and 712 g m^{-2} d^{-1}. The lower emissions in this study in comparison to Fjelsted et al. (2015) could be due to more precipitation, causing saturation of the soil.



(a) (b)

Figure 1: The average methane emission in mol m-2 day-1 as a function of the barometric pressure gradient in hPa/h at (a) Hedeland Landfill and (b) Audebo Landfill.

The results of the ground-based emission measurements at Audebo Landfill showed a high spatial variability and the magnitude of the emissions was substantially higher compared to Hedeland Landfill. The average methane emissions for the 100 measuring points varied between 6.9 mol m^{-2} d^{-1} (111 g m^{-2} d^{-1}) and 19.7 mol m^{-2} d^{-1} (314 g m^{-2} d^{-1}) over the five measuring days with peak emissions on the day with the largest negative barometric pressure gradient (1965 mol m^{-2} d^{-1} or 31 kg m^{-2} d^{-1}), see Figure 1 (b).

No correlation was observed between TIR images and LFG emissions and between LFG emissions and soil temperatures at Hedeland landfill, see

Figure 2 from December 10. In Audebo higher temperatures were registrered with the TIR images in the areas where the highest LFG emissions were also registred as can be seen in

Figure 3 from March 14. The temperature differences observed in the TIR image were only around 1,5 °C, which is very different from temperature differences reported in the literature. Tanda et al. (2017) found temperature differences ranging from 7 degrees till 10 degrees at the surface of a landfill where LFG emissions were expected. Lewis et al. (2003) found temperature differences at the surface with af TIR camera between 7 degrees and 16 degrees.

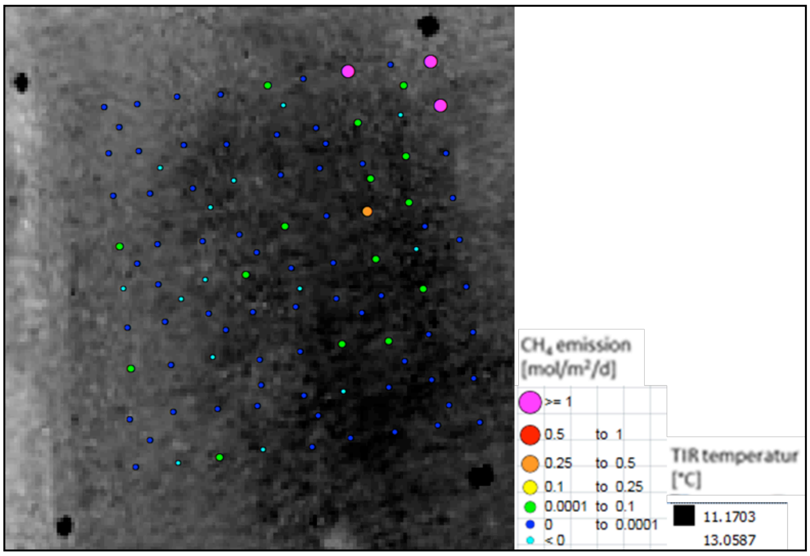


Figure 2: TIR images and methane emission at Hedeland Landfill 10/12/2015. The black marks in the corners of the TIR image are the ground control points marking the corners of the 100 m2 test area. The colored dots represent the methane emissions at the individuel 100 measuring points.

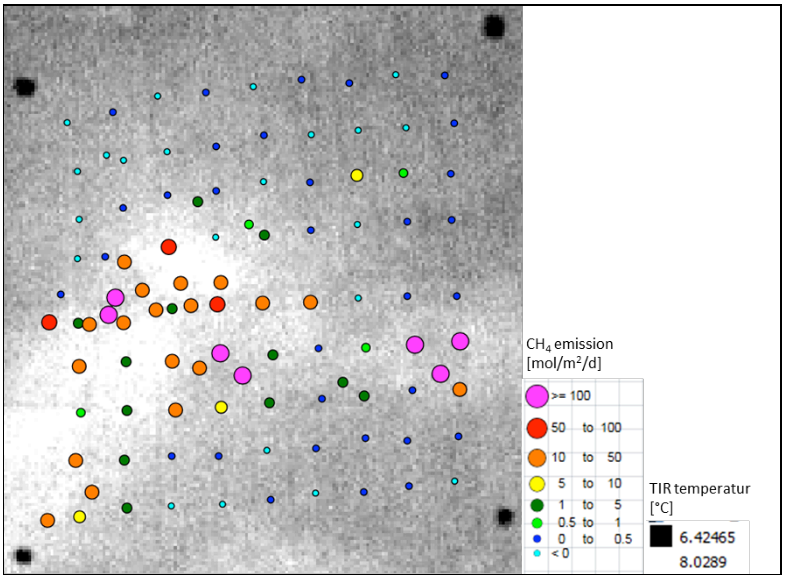


Figure 3: TIR image and methane emission at Audebo Landfill 14/03/2016. The black marks in the corners of the TIR image are the ground control points marking the corners of the 100 m2 test area. The colored dots represent the methane emissions at the individual 100 measuring points.

4. CONCLUSIONS

Surface flux chamber measurements performed at two Danish landfills showed high spatial and temporal variability in emissions. The results indicated that the ability of the TIR camera to delineate LFG emission hot spots depended on the magnitude of the LFG emissions. However, it should be underlined that the temperature differences observed in the TIR images were very small (1,5 to 3 °C) compared to what is reported in literature. The study clearly showed that the magnitude of the LFG emissions was influenced by changes in barometric pressure.

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