SPATIAL AND TEMPORAL VARIABILITY OF GAS MIGRATION AT THE SURFACE OF A MSW LANDFILL

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SUMMARY: The objective of the study was to investigate spatial and temporal variability of landfill gas emissions at an ordinary MSW landfill in order to contribute to the improvement of future gas management at landfill sites. Temporal variations of gas flux together with weather data was measured during a 16 day period, and a spatial screening of gas flux, soil gas concentraions and surface concentrations of gas was performed. The high variability of landfill gas flux that has been reported in previous studies was also shown in this study. Some general patterns in related to the varying weather conditions could also be observed.

1. INTRODUCTION

Landfills are rated as the second largest anthropogenic source of methane to the atmosphere and the migration of landfill gas from a specific landfill depends on several aspects, such as the nature of the soil cover system, the gas collection system, and daily management. Old landfills also contribute to the emission of greenhouse gases and even at sites that have been closed for twenty years or more, methane and carbon dioxide emissions are frequently detectable. Previous investigations have shown that the spatial and temporal variability of sub-surface gas migration and surface gas flux at landfills can be very high (Rachor et al., 2009 and Rosqvist et al., 2011). A better understanding of gas generation and migration at landfills will facilitate future improvement of landfill gas management.

The objective of the study was to investigate spatial and temporal variability of landfill gas emissions at an ordinary MSW landfill in order to contribute to the improvement of future gas management at landfill sites. In this paper we present results from a field campaign performed in December 2009 at the Filborna landfill in Helsingborg, Sweden. In the paper the flux variability of the surface landfill gas flux at an ordinary MSW landfill is analysed and discussed.

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2. METHODOLOGY

In a test field area of approximately 250 m^2, spatial and temporal surface flux as well as soil gas composition was investigated (Fig. 1). The test field was divided into 8 rows, which were subdivided into 5 columns, yielding a total of 40 positions, five of which were not used as the soil was inundated (left corner in Fig. 1). For the spatial variability investigation, screening of surface CH_4 concentrations, emission measurements and analysis of soil gas concentration was performed on 35 positions during two days in December 2009. Surface CH_4 concentrations were measured using a mobile flame ionization detector (FID) connected to an aluminium tube with a funnel. Emissions were determined using a static open chamber connected to an FID which was programmed to record the CH_4 concentration in the chamber once per minute. CO_2 concentrations in the chamber were automatically recorded using a diffusion-based infrared CO_2 analyzer by TSI. The soil gas composition at 20 cm depth was measured using a mobile soil gas probe that consisted of an aluminium tube (7 mm inner diameter) rammed into the soil and closed with a rubber septum. Samples were taken through the septum with a syringe and a needle, samples were taken and directly measured with a biogas-analyzer detecting CH_4, CO_2 and O_2.

The temporal variability of CH_4 and CO_2 emissions were determined using static chamber measurements in four plots, A-D, for almost 16 days during the period November 29 to December 17 (Fig. 1). The static chamber was connected to the sample gas inlet and outlet of an NDIR gas analyser (Siemens, Ultramat 23) via plastic tubes. The concentrations of CH_4 and CO_2 were analysed continuously with infrared technology, and manually read on the instrument display in one minute intervals.

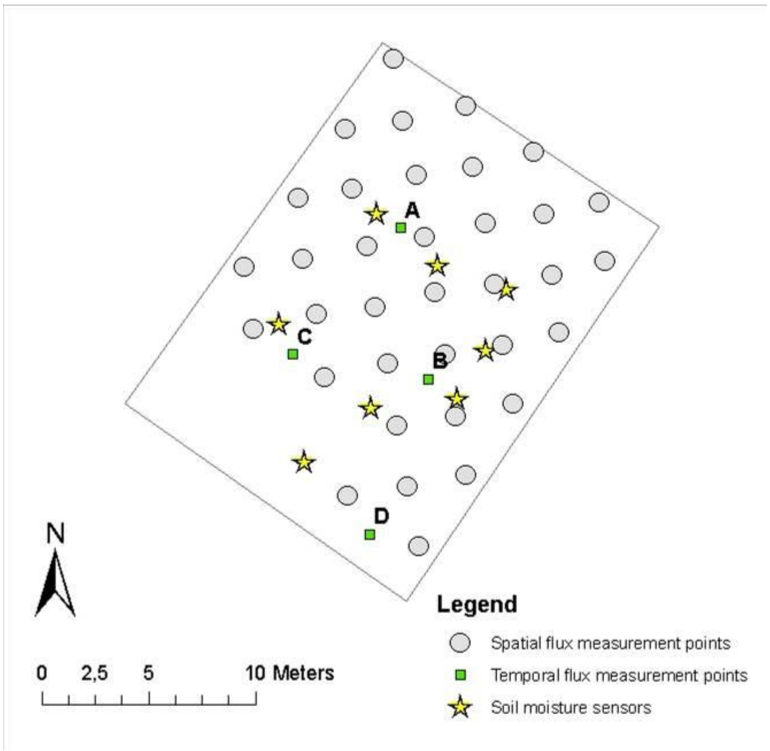

Figure 1. Plan of the test field area showing spatial and temporal gas flux measurement points and points for soil moisture sensors

In addition to gas flux measurements also air pressure, precipitation, soil temperature (5 cm depth below soil surface) and air temperature were logged at a weather station in the vicinity of the investigation area. Six soil moisture sensors (Delta-T Devices, SM2000) connected to a logger (Delta-T Devices, DL6) measured soil moisture at 5 cm depth (Fig. 1).

3. RESULTS

3.1 Weather data

The weather conditions varied strongly during the field campaign, from November 29 to the December 17. During December 1 to December 3, the soil was frozen; thereafter the soil temperature increased and the soil began to thaw. In figure 2, recorded soil temperature and air pressure are shown. Since high air pressure is related to clear cloudless weather, the air temperature often decrease at higher air pressure during winter. The soil temperature dropped from time to time below 0 ºC from December 12 and onwards.

From December 15 it began to snow, and on December 16 the investigation area was partly covered with a thin snow cover. At December 17 the investigation area was completely covered with a thick layer of snow. In figure 3, precipitation and soil moisture from one of the six sensors is shown. Two major rain events (December 7 and December 10) had a significant impact on the soil moisture. The precipitation during December 16 was in the form of snow. The recorded soil moisture data was disturbed during the periods of frozen soil and was therefore removed from the data set.

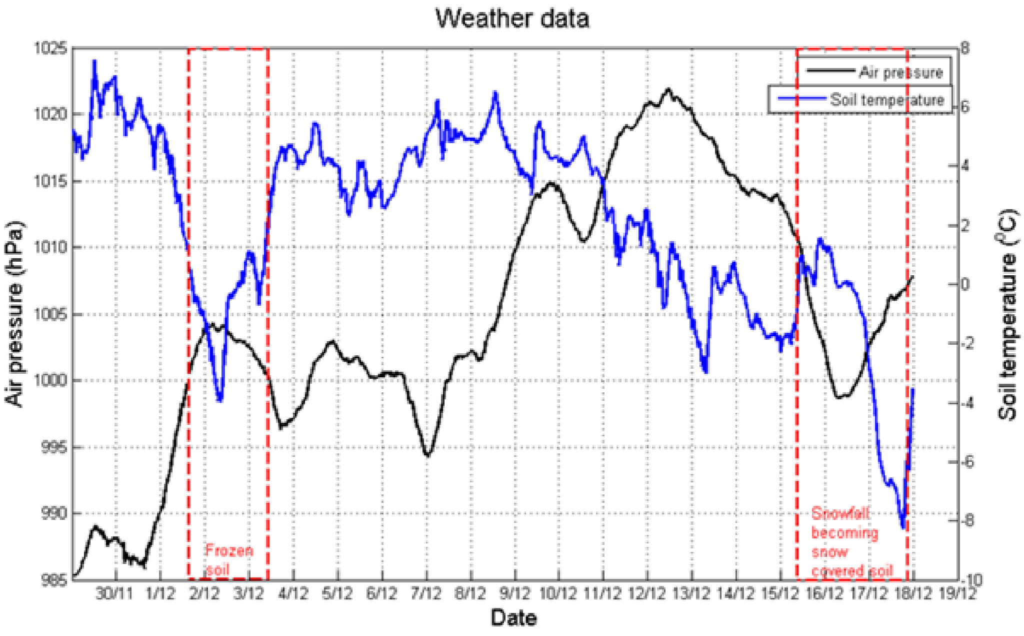

Figure 2. Air pressure and soil temperature measured at the weather station during the investigation period, with the timing of special weather events marked (i.e., frozen soil and snow fall resulting in snow cowered area)

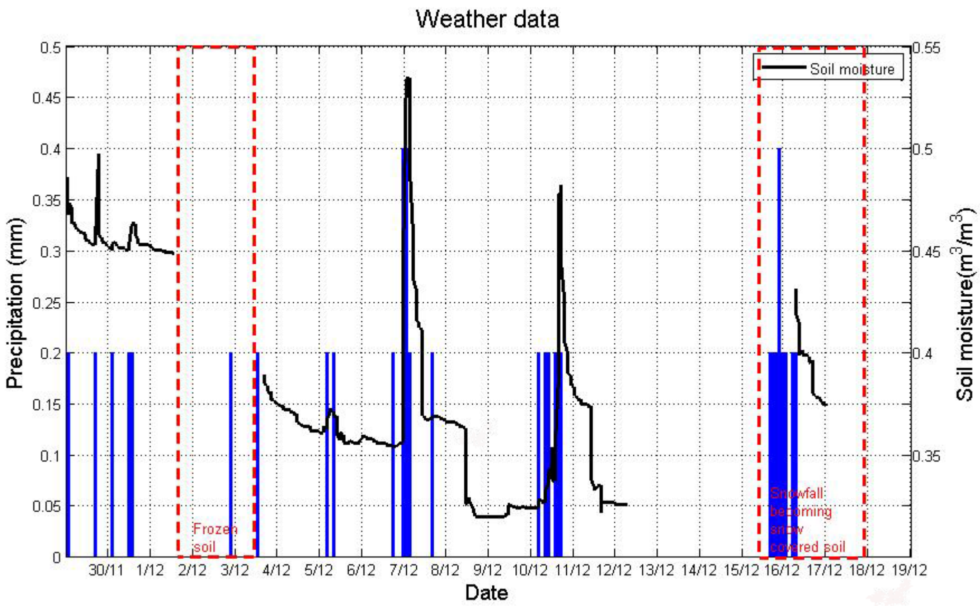

Figure 3. Precipitation measured at the weather station and soil moisture data during the investigation period, with the timing of special weather events marked

3.2 Spatial distribution of gas flux

The screening of surface CH_4 concentrations showed high spatial variability (data not shown) and high emission rates in a limited area located at Y=0-8 m and X= 0-10 m (Fig. 4). The pattern of emissions on the two days when measurements for spatial distribution was performed (December 2 and 3) remained roughly similar, but the magnitude of CH_4 emissions from the same spot varied by a factor of 0.4 to 5.1 (Fig. 4), indicating strong temporal variability on the time scale of days.

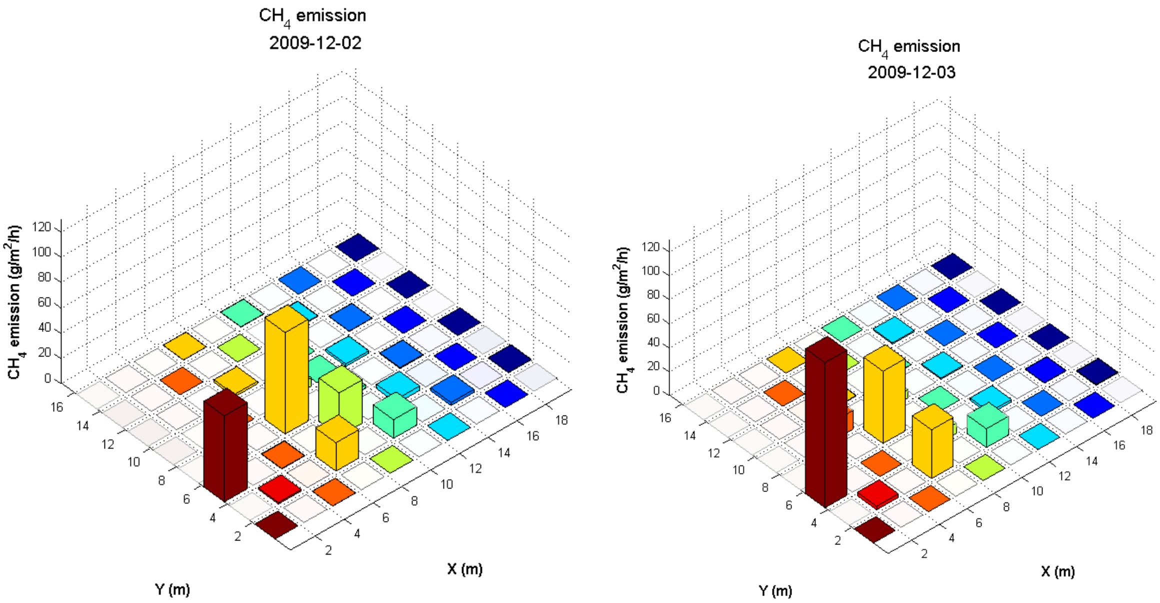

Figure 4. Results of the screening of surface CH_4 flux from December 2 and 3

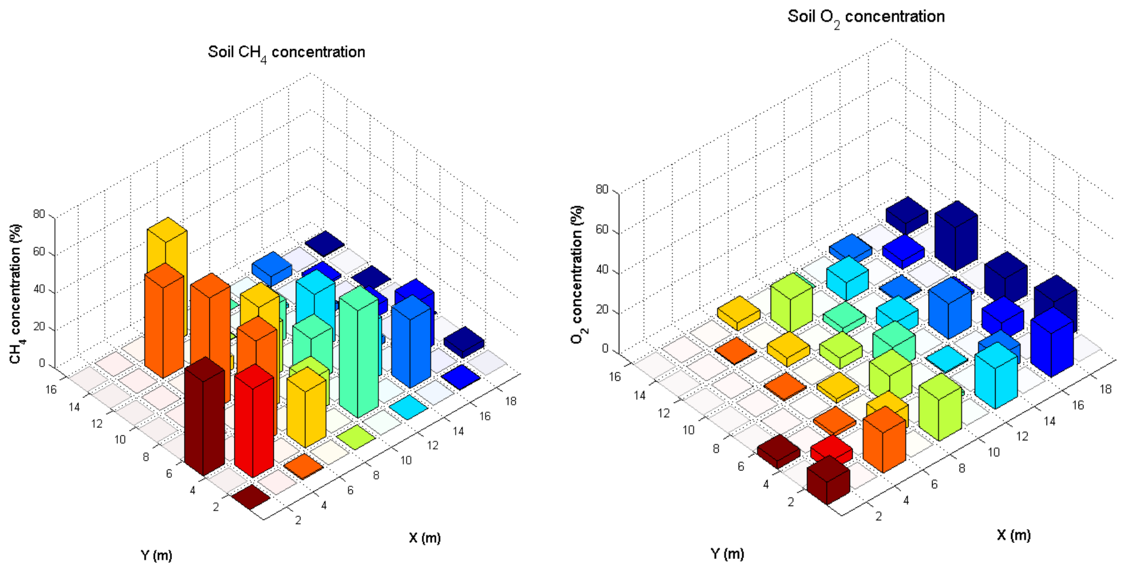

Figure 5. Results of the screening of soil CH_4 and O_2 concentrations in 20 cm depth on December 3.

The screening of gas composition at 20 cm depth also indicated a spatial variability (Fig 5). However, the CH_4 concentrations (Fig. 5, left) differed from the observed CH_4 emission pattern (Fig. 4). This indicates that the factors governing soil gas composition and those governing emission may not be the same or that processes such as methane oxidation and/or soil respiration are effective in the top 20 cm of the soil.

Another possible explanation is that the soil surface has a very low permeability at certain locations, which prevents gas leakage from the soil even though the gas concentration below the soil surface is high. The frozen soil conditions during the December 2 and 3 could be a probable explanation to a constrained permeability through the soil surface.

A comparison between soil CH_4 and O_2 concentrations (Fig. 5) indicate that the oxygen level is often low where the methane concentration is high. Thus, these two screenings complement each other and provide a rough picture of the locations of aerobic versus anaerobic soil environments in the investigation area.

3.3 Temporal variations of gas flux

The results of the long-term measurements in four plots (Fig.1; A-D) showed high temporal gas flux variability. Table 1 shows summarizing statistics for the temporal flux measurements of CH_4 and CO_2. Plot B, C and D showed roughly similar gas flux levels varying from very low flux rates to over 120 $g/m^2/h$ of CO_2, whereas in plot A, both CH_4- and CO_2-fluxes were very low during the whole measuring period. The median value of 0.00 $g/m^2/h$ at plot A shows that there was no CH_4-flux at this location during most of the measurement period. The negative minimum value of CH_4-flux is probably a result of the absence of CH_4-flux and a simultaneous positive CO_2-flux; an increase in CO_2-concentration in the static chamber, then result in a relative decrease of CH_4-concentration.

The gas flux variability in the data sets from plots B, C and D expressed as standard deviation ranged between 1.47 to 2.14, showing a high and relatively similar level, whereas the variability in plot A was very low, 0.07 (Table 1). Thus, plot A differs from the other measurement plots, both in absolute flux values and in the spreading of the data.

Below, flux measurements at plots A to D are presented and the characteristics of each of the plots are analysed and described. Figure 6 shows that the CH_4 fluxes at plot A were very low (almost zero) during the period from November 29 to December 10, and during the period December 10 – December 15 increasing CH_4 fluxes were measured. Also the CO_2-fluxes at plot A were very low during the period of measurements, but did not show the same pattern as the CH_4-fluxes.

In contrast to plot A, the variations of the CH_4- and CO_2-fluxes showed similar patterns at plot B (Fig. 7). The fluxes were also approximately a factor 20 times larger, compared to plot A. Particularly high values were measured at three different occasions; during December 2 when the soil was frozen, during December 5 and during December 15 – December 16.

The mean value of the fluxes measured at plot C were in the same order of magnitude as plot B (Table 1), but the pattern of the variations differed (Fig. 8). At Plot C, the CH_4-fluxes were most often below 40g/m^2/h during the first five days of the measurement period where after the variation became larger during the December 7 to December 12. The maximum value of both CH_4- and CO_2- flux was measured during December 10. During the last three days, the CH_4-fluxes seemed to stabilize again at approximately 20-60g/m^2/h.

Figure 9 shows the fluxes measured at plot D. The variation of the fluxes shows a relatively clear

Table 1. Summarizing statistics from temporal measurements of CH_4- and CO_2-flux

	A (g/m^2/h)		*B* (g/m^2/h)		*C* (g/m2/h)		*D* (g/m^2/h)	
	CH_4	CO_2	CH_4	CO_2	CH_4	CO_2	CH_4	CO_2
Mean value	0.33	1.33	20.6	35.5	25.4	35.9	16.7	29.6
Std. deviation	0.07	0.10	1.91	3.45	2.14	3.00	1.47	2.64
Median value	0.00	1.05	14.8	25.1	21.6	28.3	11.5	20.4
Min value	-0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Max value	4.32	5.11	78.9	143.5	98.4	123.4	75.7	123.4

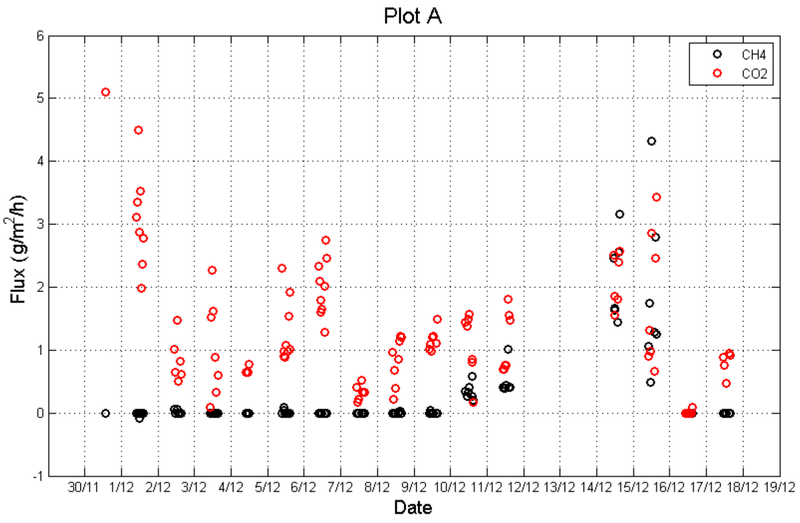

Figure 6. Result of gas flux measurements (CH_4 and CO_2) at plot A

trend, with CH_4-fluxes almost constantly below 20g/m^2/h from December 1 to 9. From December 10 to 15 both CH_4- and CO_2-fluxes becomes noticeably higher, where after they suddenly decline during December 16 to 17.

During the period of measurements for determination of temporal variability highly variable CH_4 and CO_2 fluxes were measured and few general patterns in the variations of gas flux could be observed at the four measurement plots, except for a general decline of the flux rate during the end of the measurement period. At December 16, the fluxes were close to zero at measurement plots A and D, and at December 17, the fluxes were close to zero at all measurement plots. Since there was a snow cover built up during that period it is suggested that the snow cover prevented gas emissions to the atmosphere. At measurement plot C, high fluxes were measured after the major rain events during December 7 and December 10. At December 10, maximum flux of both CH_4 and CO_2 were measured also at plot D.

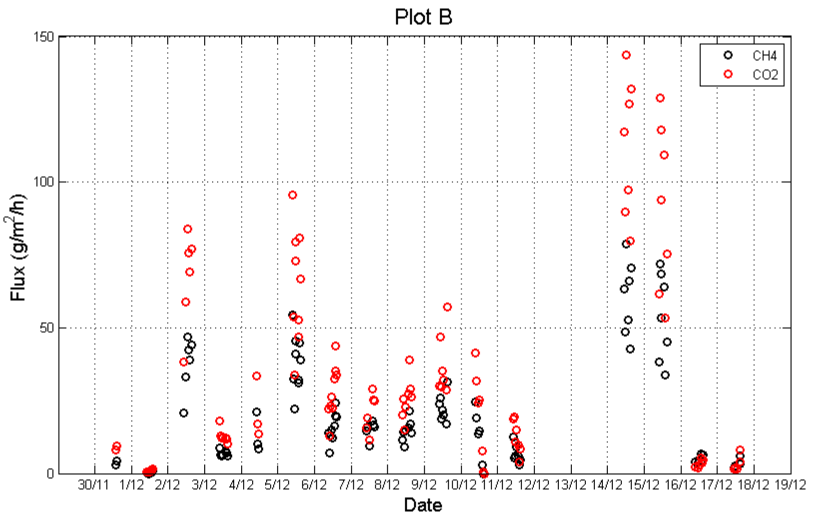

Figure 7. Result of gas flux measurements (CH_4 and CO_2) at plot B

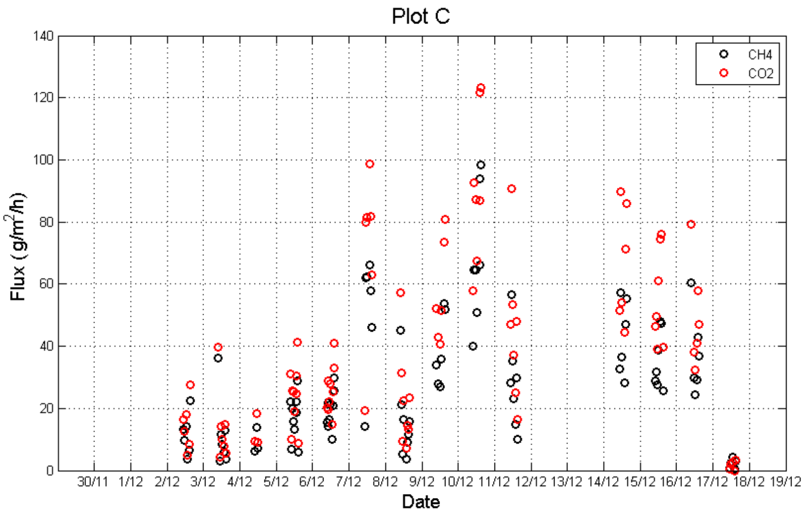

Figure 8. Result of gas flux measurements (CH_4 and CO_2) at plot C

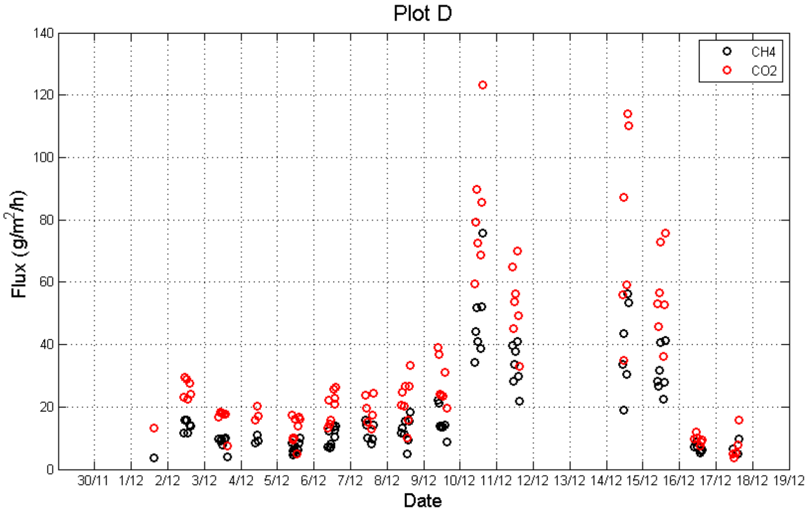

Figure 9. Result of gas flux measurements (CH_4 and CO_2) at plot D

4. DISCUSSION

The high variability of landfill gas flux, that has been reported in previous studies (e.g., Rachor et al., 2009), was also shown in this study. Spatial as well as temporal variability was clearly shown in the measurements and it was concluded that some common features in the spatial and temporal variability was shown in the area located at Y = 0-8 m and X = 0-10 m (Fig. 4) at December 2 and December 3. The temporal measurements of gas flux also showed an agreement with the soil gas concentrations (Fig. 5), assuming that the pattern of the soil gas composition is relatively constant throughout the measurement period. At plots C and D relatively low fluxes were measured during December 2 and December 3, but the overall mean values of these plots were high. A comparison between Fig. 5 (left), the locations of the temporal flux measurement plots in Fig.1 and the mean values in Table 1 suggest an agreement between soil gas composition and long-term gas flux.

At plot A, both CO_2- and CH_4-fluxes were very low which can be the result of either a low-permeable soil surface or low gas concentrations in the soil at 20 cm depths. The screening of soil gas concentration indicates O_2 presence and a relatively low CH_4 concentration in that part of the test field, which suggests that the soil 20 cm below the soil surface was in contact with the atmosphere and hence conditions were favourable for methanotrophic activity. Aerobic conditions in the soil would explain why only CO_2-fluxes were detectable during November 30 to December 9 at Plot A. After the larger rain event during December 10, CH_4-fluxes start to appear at plot A, albeit of low magnitude compared to the other plots. This suggests that the rate of methane oxidation in the soil decreased as a consequence of less oxygen in the soil after the intense precipitation event.

The mean values of the fluxes were in the same order of magnitude at plots B, C and D but the pattern of the variations differed between the plots. The particular high fluxes measured at plots C and D after the major rain events during December 7 and December 10 are likely a response to pressure build up due to infiltrating water. A similar pattern was seen at the same landfill during field measurements in August 2008 (Johansson et al., 2011).

REFERENCES

Johansson, S., Rosqvist, H., Svensson, M., Dahlin, T., Leroux, V. (2011) An alternative methodology for the analysis of electrical resistivity data from a soil gas study. Accepted for Geophysical Journal Internatonal (2011 May 13).

Rachor, I., Streese-Kleeberg, J., and Gebert, J. (2009) Spatial and temporal variability of gas emissions from old landfills. Proceedings Sardinia 2009, Twelfth International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy.

Rosqvist, H., Leroux, V., Dahlin, T, Svensson, M., Lindsjö, M., Månsson C-M., and Johansson, S. (2011) Mapping landfill gas migration using resistivity monitoring. Waste and Resource Management, 164:2-15.