Gaseous emissions reduction from aerobic MBT of municipal solid waste

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Abstract

Surface gaseous emissions, composition of soil gas and VOC concentration were determined on a French MBT plant, where the biodegradation process is aerobic. Measurements were performed on both the composting windrows and on the landfill cell which receives the sorting rejects. This allowed the comparison of the global methane and CO2 gases, as well as the characterization of the degradation process on the different parts of the site. The performance of the sorting chain allow to obtain a high-grade compost, which can be valorised on agricultural fields, and leads to deposit much smaller quantities of degradable waste than in a classical landfill site, and to lowering seriously the generation of methane. Therefore, landfill gas (LFG) does not need to be recovered and treated by classical means, e.g. flares.

Keywords:

aerobic MBT, gaseous emissions, landfill cell, surface flux, VOC

1 Introduction

Mechanical biological (MBT) treatment of municipal solid waste (MSW) is mainly used to stabilize the organic matter prior to landfilling. Other processes allow energy recovery (by collecting biogas generated during anaerobic digestion) and/or return of organic matter to the soil. Different processes exist. We have evaluated the gaseous emissions of one of the French MBT aerobic plants within two different studies. The first study aimed to measure the gaseous emissions during the composting process, and the second one focused on the biogas generation from the associated landfill. In order to characterize the gaseous emissions, several direct and indirect measurement methods were used during two campaigns, respectively on the composting plant, then on the two first cells of the landfill. Some methods were used on both the composting plant and the landfill, allowing the comparison between surface fluxes and biogas composition.

2 Composting process

Municipal solid waste is received in bags from door-to-door collection. The first step is an aerobic biological pretreatment in two composting drums, where bags are opened and waste is physically and biologically pre-degraded. The duration of this step is 3 to 4 days, in order to initiate the degradation of paper and cardboard. Then, a high grade sorting process is undertaken, the final separation being done at a 10 mm mesh. Thus, the fine and biodegradable fraction of the waste is well separated and goes to the composting hall, where it is mixed with screened green waste compost at a 2:1 ratio. Composting of the biodegradable fraction is done in turned windrows, passively aerated. The rejected coarse fraction is landfilled close to the plant.

3 Material and methods

The investigation covered three composting windrows of different ages and two cells of the in-site landfill:

- windrow A, situated in an open shelter, was constituted between one and two weeks prior to the first measuring day, and was turned by an automatic machine twice a week,
- windrow B, also under the shelter , was constituted between 15 days and one month before the first measurement, and was also turned twice a week,
- windrow C, outside the shelter, was at least 2 months old when the measurements started and was not turned,
- cell 1 of the landfill was rehabilitated. It has a 1 m clay cover plus planted soil;
- cell 2 was full of the composting rejects, but uncovered yet at the time of measurements. Therefore we expected the maximum surface emissions from this cell.

Gaseous emissions were characterized by different techniques:

- Three different devices were used for surface emission measurements on the composting windrows: two flux chambers (one static, one dynamic) and one tunnel; low concentrations of methane (CH_4), carbon dioxide (CO_2), ammonia (NH_3) and nitrous oxide (N_2O) were monitored by an FID (Autofim II) specifically for methane and a photo acoustic analyzer (Innova) for all these gases; higher concentrations of CH_4 and CO_2 were measured with an infrared portable apparatus (Ecoprobe 5). The static chamber was also used for surface flux measurements on the cell n° 2 of the landfill,

- Composition of the soil gas (CH_4, CO_2) was assessed by the use of a probe and the portable analyzer Ecoprobe 5; these measurements were performed on both the windrows (where “soil” means compost) and the landfill cell,
- Concentrations of trace gases (VOC) were established on some samples taken on the static chamber, also on the windrows and the landfill cell surface.

Due to the relatively high porosity of the material compared to the soil which are usually scanned with the static chamber, there were some differences between the fluxes determined with the static chamber and the dynamic one on the compost windrows (fluxes measured with the static chamber being the lowest). Results of the comparison of the techniques will be published elsewhere (report: MALLARD *ET AL*, 2008). The flux measured with the static chamber represents more or less the gaseous flux emitted by the surface of the windrows in a total absence of convective gas flows. Nevertheless, due to the short measurement time, a large number of local fluxes can be determined with this method, allowing the interpolation and cartography of the surface emissions.

3.1 Surface fluxes measurements

Measurements of methane and carbon dioxide surface fluxes were performed with a patented static chamber (see Figure 1). Monitoring of the gas concentration increases in the chamber was done in parallel with a flame ionization detector (FID) for low concentrations of methane (down to 1-2 ppmv), and a CH_4/CO_2 infra-red analyzer (Ecoprobe 5) for larger concentrations (up to 100 % v/v). Interpolation of these points gives access to the cartography of global emissions and to the mean surface fluxes. Methane and CO_2 fluxes were calculated for windrows of different ages, and for the landfill cell, allowing the comparison of emissions between the composting process and the landfill.

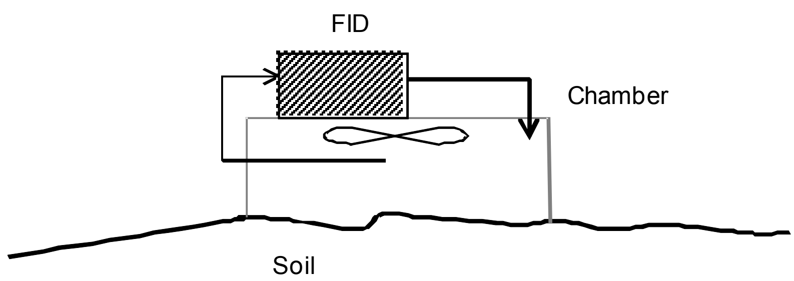

Figure 1 : apparatus for gaseous surface emissions (static chamber)

3.2 Composition of biogas

Composition of the biogas was determined at 1 meter depth with a soil gas probe and the Ecoprobe 5 analyzer. The analyzer also comprises an electrochemical cell to measure oxygen concentrations in the soil gas.

Photo 1 : CH_4 and CO_2 measurements on soil gas (Ecoprobe 5)

3.3 Trace VOC emission

Some VOC samples were taken on the flux chamber for identification and quantification, following US-EPA TO15 and TO17 air toxic methods. Sampling was done using the following methods:

- on the windrows, sampling was performed by pumping 1 liter of chamber air on 3-zones adsorbent tubes (“Air Toxics” type) at 100ml/min, thus the sampling time is 10 minutes. On some points, during the time period of air sampling, the combustible gases (methane + trace VOC) concentration increase was monitored by the FID, which allowed an estimation of the VOC fluxes, using the hypothesis that VOC concentrations follow the global combustible gas monitored by the FID,
- on the landfill cell, air from the chamber was sampled by diffusion in an emptied steel canister. This method theoretically gives access do compounds of low molecular weight which are not stable on solid adsorbents, such as vinyl chloride.

Analysis was done by preconcentration on Perkin Elmer ATD400 or Turbomatrix (with the thermodesorption of the adsorbent tubes), gas chromatography and mass spectrometry. This method allows the identification of VOC, and the quantification down to 1 $\mu g/m^3$ for the most usual compounds, by using standard gas mixtures of aromatic and chlorinated compounds. On the landfill cell 2, toxic compounds: BTEX and chlorinated solvents, were specifically searched. On the windrows, the analysis purpose was different: identification of the major VOC by the mass detector, and quantification of the most abundant ones.

4 Results

4.1 Surface emissions of CH_4 and CO_2: comparison between the windrows and the landfill cell

The first finding is that methane emissions from the open cell of the landfill are very low: see Figure 2. It comes from the fact that a large part of the organic matter is diverted from the waste to the composting process. Waste which is landfilled contains mostly materials such as plastics, foams… which are not easily biodegraded.

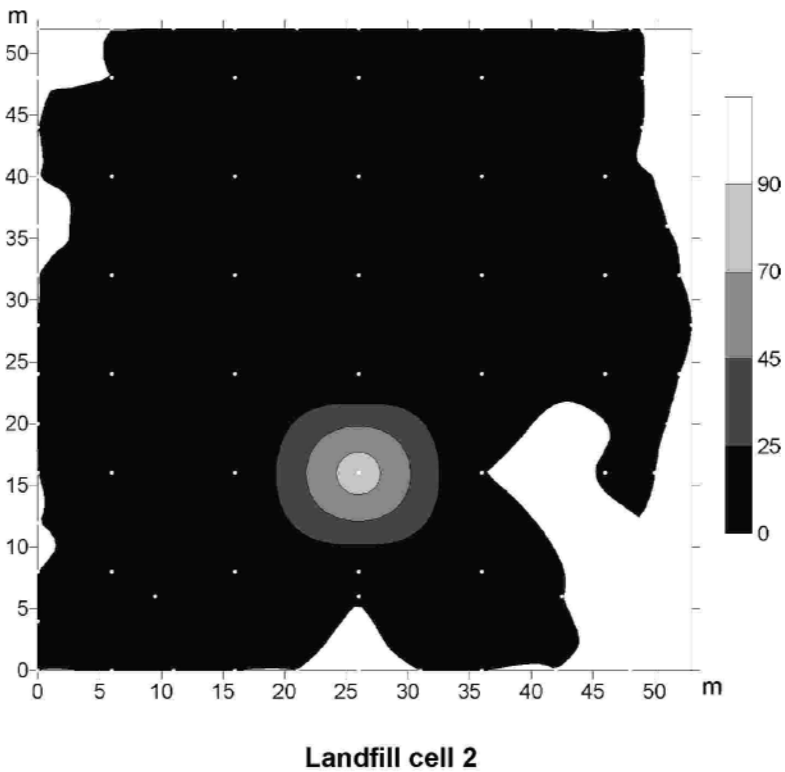

Figure 2 : Interpolated methane emissions on landfill cell 2, ml/m^2/min

Methane emissions from the three composting windrows are very different, as shown on Figure 3, due to the “age” of the material - e.g. the stabilization of the organic matter. Methane emission increases with the age of the windrow, but also when the windrow is not turned (windrow C). Furthermore, methane emissions are higher at the top of the windrow, which is natural, as temperature – measured in the same time with an infrared camera – and gas fluxes are known to be higher at tops.

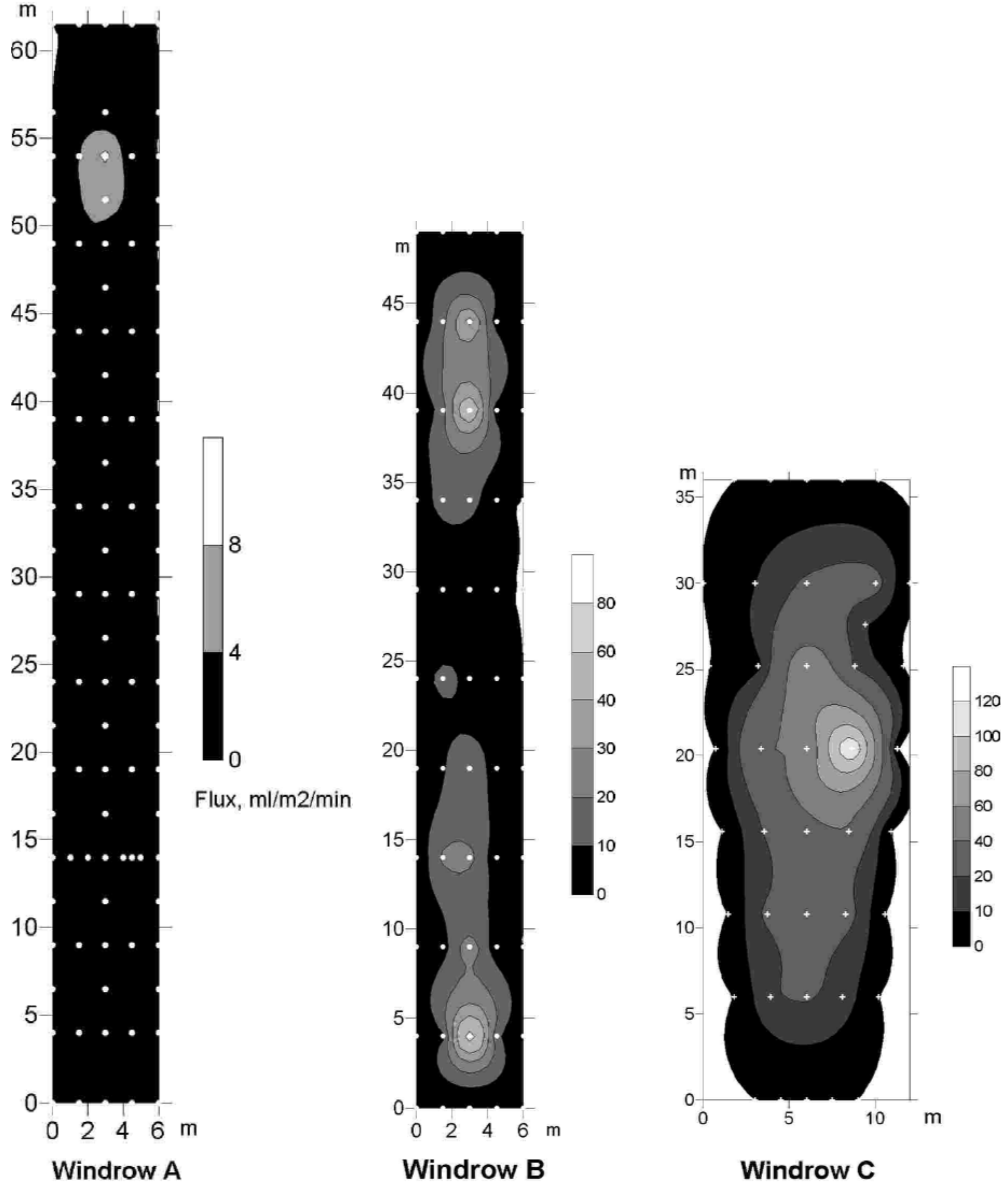

Figure 3 : Interpolated methane emissions on windrows, mL/m^2/min

Meanwhile, CO_2 emissions are more stable, indicating the constancy of the aerobic degradation. Therefore, the interpolations of CO_2 fluxes on the different parts of the site are not detailed here.

The major finding is the comparison of the surface emissions between the composting plant and the landfill cell measured with the static chamber. Results are given in the Table 1.

Table 1 : CH4 and CO2 fluxes on composting windrows and the landfill cell

	Composting plant : windrows			**Landfill, cell 2 : waste refuse**
	A	**B**	**C ***	
Age of the windrow/storage	2 weeks	1 month	2-3 months	< 2 years
Interpolated surface area, m^2	368	293	382	2760
Mean CH_4 flux, $L{\cdot}h^{-1}{\cdot}m^{-2}$	0,08	0,60	1,1	0,25**
Mean CO_2 flux, $L{\cdot}h^{-1}{\cdot}m^{-2}$	6,4	8,3	6,0	2,3
Total CH_4 flux on each part, m^3/h	0.029	0.176	0.42	0.69
Total CO_2 flux on each part, m^3/h	2.36	2.43	2.29	8.65

* *maturation step, not turned; ** methane is partially oxidized through the surface layer*

Mean carbon dioxide fluxes are quite similar on each windrow, whatever their age. Mean emissions from the landfill are a little smaller, indicating that aerobic degradation process is less important in the landfill cell.

Methane emissions vary more, from a small value on the younger windrow (2 weeks) to a higher one on the older windrow. This latter value is mainly due to a singular point which shows a high methane flux on this windrow (7.3 $L{\cdot}h^{-1}{\cdot}m^{-2}$). In comparison, mean methane emission is smaller on the landfill, than on two of the 3 windrows, due to low organic content of waste and partial oxidation in the cell cover (results will be published elsewhere : BOUR *ET AL*, 2009). Landfilling of the rejected fraction from composting, which contains a small proportion of organic matter and is partially stabilized, leads to small methane emissions, which do not need to be recovered. A simple oxidizing cover could be sufficient to manage this residual emission, with special care on rainwater management.

Because of the surface area involved, both methane and CO_2 emissions are comparable with the sum of the emissions of the windrows. This shows that in the case of MBT prior to landfilling of municipal waste, it is important to take into account both the emissions of the landfill site and of the MBT plant, particularly in this case where the composting material is rather fine and thus poorly aerated, leading to significant emission rates of methane.

4.2 Gas composition in the compost

As for the surface fluxes, windrows of different ages and the landfill cell n° 2 were studied. Methane and CO2 concentrations at 1 m depth are given by the Ecoprobe 5. The repartition in composition for both the windrows and the landfill cell are given in figures 4 and 5 under box-plot graphs.

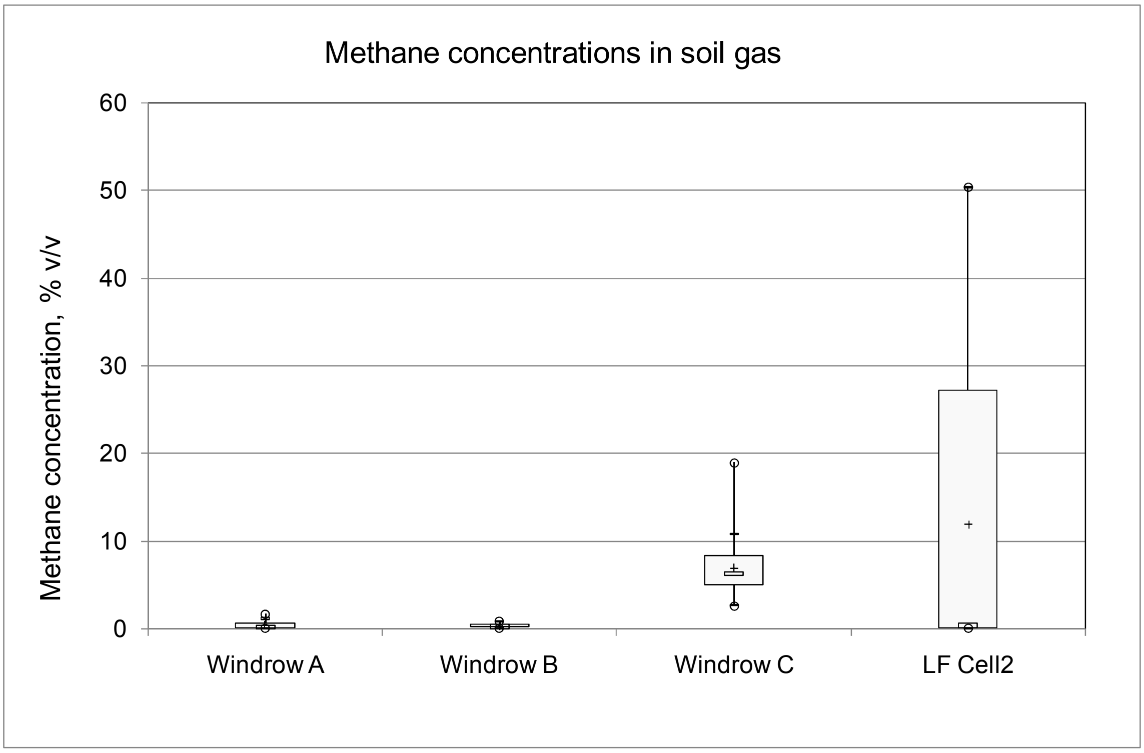

Figure 4 : repartition of methane values in soil gas, windrows and landfill cell

Methane concentrations are very low (mostly null) in the younger windrows, A and B. Windrow C, which is older and not turned (thus having less oxygen available for biodegratation processes) contains more methane: mean concentration is 6.9 % v/v, median value is 6.2. The higher concentration measured at 1 m depth on windrow C corresponds to the higher methane surface flux. The landfill cell has a very different behavior: methane concentrations are very dispersed, from 0 to 50 % v/v, the mean and median values are different.

CO_2 concentrations show a different behavior: most values are very similar for the three different windrows, and close to 17 % v/v, which correspond to the consumption of the atmospheric oxygen in aerobic degradation. Mean and median values are also very close, which confirms that the degradation processes are the same within the three windrows. On the contrary, CO_2 concentrations at 1 m depth in the landfill cell are very similar to the methane concentrations at the same location, indicating that the soil gas is a mixture of methane and CO_2 in similar proportions. This is the signature of a typical biogas emitted by the anaerobic degradation of municipal waste.

Both methane and CO_2 concentration values inside the landfill cell are much dispersed: one can imagine that the landfilled waste, which is very heterogeneous, has a variable amount of residual organic matter.

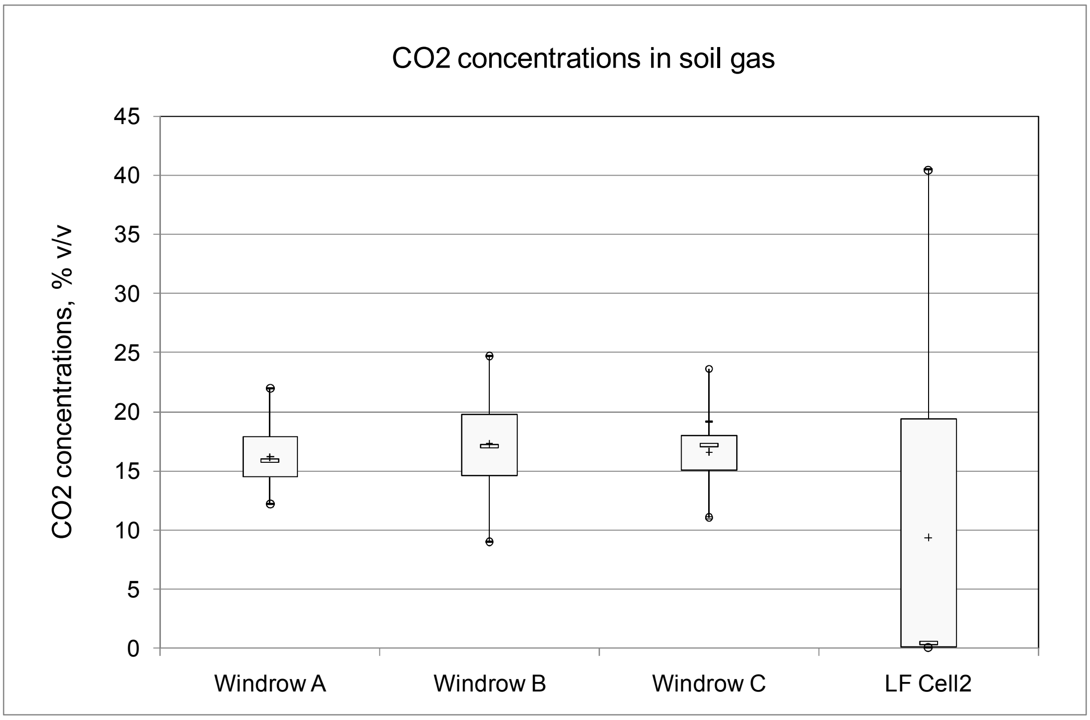

Figure 5 : repartition of CO2 values in soil gas, windrows and landfill cell

4.3 Effect of windrow turning on the gas concentrations

The effect of windrow turning has been assessed by CH_4 and CO_2 in 1-meter depth measurements repeated within 24 hours after the turn.

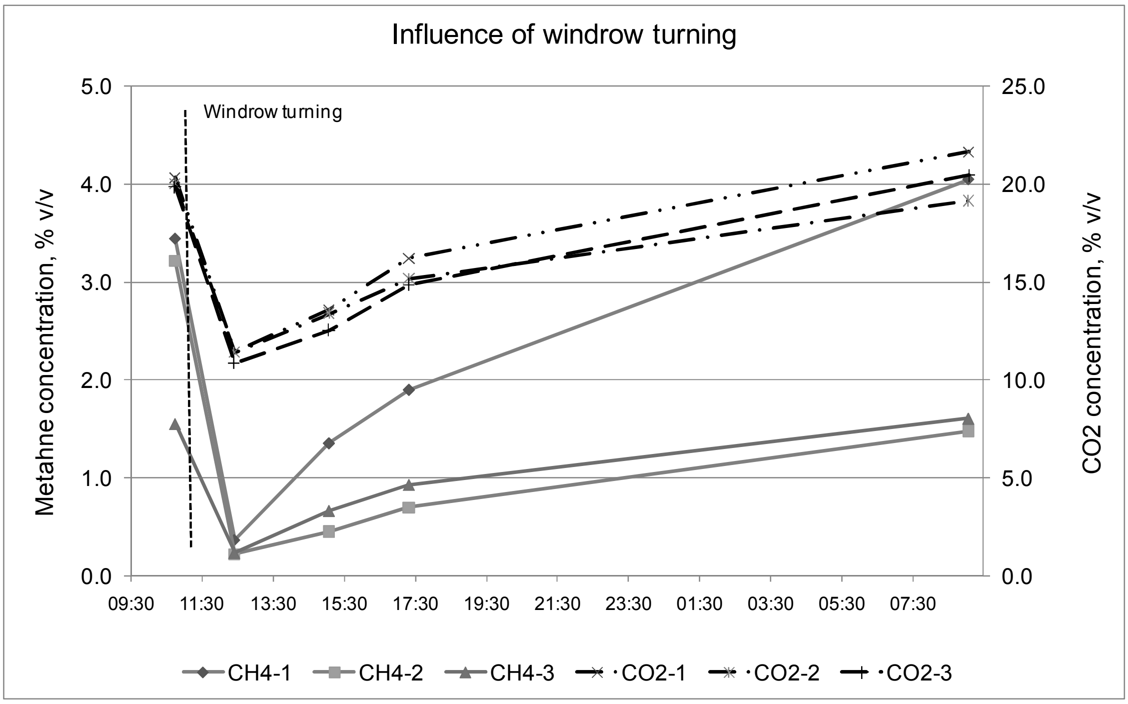

Figure 6 : effect of windrow turning on CH4 and CO2 concentrations in the compost

CO_2 and CH_4 concentrations are considerably lowered just after turning of the windrow. However, after 24 hours, these concentrations are quite the same as before the turning. This shows that the available oxygen does not last long inside the windrow. The substrate is relatively fine and homogeneous, it is therefore important to turn regularly the windrows, which is done at least twice a week on this plant.

Since these measurements, improvements have been brought to the process. The following changes will be made in the composting process itself. In order to obtain an optimum biodegradation, organic matter extracted from the municipal waste will be mixed with crushed vegetal residues, and the process will be operated in closed boxes with forced aeration, in order to keep a higher amount of oxygen within the material, helping the aerobic biodegradation.

4.4 Surface VOC emissions

4.4.1 Composition

As the analytical procedures for identification were different between the samples from the windrows and the landfill cell, it is not possible to compare exactly all the VOC present in all the samples. But tendencies can be established. Major results are given in Table 2.

Concerning the presence of toxic compounds, the major finding is that trichloroethylene and tetrachloroethylene were never detected on any of the samples. Benzene and toluene are, except in one case, never detected on the samples taken on the windrows. Meanwhile, they are present on the two samples taken on the landfill cell 2, but at rather low concentrations. This is always the case for MSW landfills Their presence in the landfill gas shows that, or the stored waste probably contains some industrial waste, or they come from the degradation of higher molecular weight compounds. More work would be needed to clear this point. Nevertheless, the low concentration level indicates that these compounds will not be responsible for a health risk.

There are more VOC, and at larger concentrations, in the gas samples taken on the windrows that on the landfill cell. Several compounds such as the terpenes (a-pinene, limonene) come from the green waste which is crushed and mixed to the organic matter of the municipal waste. The other compounds probably come from the municipal waste, and are combined with the organic matter which undergoes composting. A-pinene and limonene on the landfill cell probably come from the crushed bark used as a temporary cover.

Table 2 : VOC composition of air samples taken on the static flux chamber

Compounds	Wind. A, 2	Wind. A, 21	Wind. B', 82	Wind. C, top	Wind. B, C8	Cell 2 Can 4	Cell 2 Can I
Ethanol	2354	1496			70		
Pent-1-ene			356	1058			
Pentane		969	846	569			
Acetone	1989	481			1693		
Dimethylsulfide			1350	383			
Methyl vinyl cetone	1302				1287		
Butan-2-one (MEK)	4503	1158			6481		
Butan-2-ol	2774	1000			5628		
Benzene			147			32	5
Pentan-2-one					283		
Methyl-3 butanol	505				416		
n-Heptane						66	15
Toluene						203	20
Octane			124	127		33	8
m+p Xylenes			53		77	299	14
o-Xylene + Styrene			90	30	51	214	10
a-Pinene			289	50	313	1506	57
Decane					128	50	46
Limonene	1961	3	12266	862	2341	540	341
Undecane			264				

Concentrations are given in $\mu g/m^3$

4.4.2 Estimation of VOC surface fluxes

While the air was sampled on adsorbent tubes, the flammable gas concentration was monitored by the FID on some sampling points. We used the hypothesis that VOC concentrations follow the global flammable gas concentration in order to evaluate the VOC fluxes. Partial results, calculated on one point, are given in Table 3.

As the measured concentration of VOC in the static air chamber are low (in the $\mu g/m^3$ range), the corresponding fluxes are naturally very low. Though these fluxes were not measured directly, this calculation helps to evaluate local VOC emissions from the composting windrows. This work needs to be continued to get better precision.

Table 3 : approximate VOC fluxes, point n° 2 on the windrow A

Compound	Flux, $\mu l/m^2/min$
Ethanol	29.4
Acetone	19.7
Acetate de methyle	5.8
Methyl vinyl cetone	10.7
Butan-2-one (MEK)	36.0
Butan-2-ol	21.8
Acetate d'ethyle	8.4
Methyl-3 butanol	3.3
Limonene	8.3

5 Conclusions

The two different studies on the gaseous emissions of a French MBT plant and the associated landfill gave the opportunity to compare the relative impacts of the plant and of the landfill. Due to the fact that a large part of the organic matter is sorted out from the MSW to undergo composting, the gaseous emissions of the landfill cell are really lowered compared to a classical landfill without MBT. In addition, the sorting of the waste is sufficiently efficient to obtain a high grade compost, which allows its use in amending agricultural soils.

6 References

Bour, Zdanevitch, Briand, Llinas	2009	“Estimating methane emission and oxidation from two temporary covers on landfilling of MBT treated waste”. Submitted for presentation to the Sardinia 2009 symposium
Mallard, Zdanevitch, Pradelle, Frejafon	2008	« Projet EMISITE: évaluation sur site de différentes méthodes de mesure des émissions gazeuses d’une installation de compostage » Final report, ADEME n° 0675c0081, August 2008

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