Mechanical - Biological Treatment and residual waste landfill in France: a case study.

Rémy Bayard*, C. de Brauer*, G. Ducom*, J. de Araújo Morais*, F. Achour*, R. Moretto•, P. Naquin•, B. Sarrazin•, J.P. Gourc°, L. Riquier♦, J. Berthet♦

*LAEPSI, INSA, Villeurbanne, France; •POLDEN, INSAVALOR, Villeurbanne, France; °LIRIGM, Grenoble, France; ♦VALDECH, Inc., Lons le Saunier, France

Abstract

In partnership with a local waste management public organisation (SDEE Mende, Lozère, France), the French Environmental Protection Agency ADEME started a research program involving several research laboratories:

- to evaluate the efficiency of the Mechanical – Biological pre-Treatment (MBT) of Municipal Solid Waste (MSW) and,
- to study, on a full-scale basis, the disposal and emissions behaviour of the pre-treated waste.

Under activity since july 2004, the site includes mechanical sorting operations, a Rotating Sequential Bioreactor (RSB), controlled aerobic stabilisation corridors, maturation platforms and a sanitary landfill site for waste disposal in separated cells.

Keywords

MSW, MBT, Mass balance, Settlement, Gas emission, Leachate emission.

1 Introduction

The inherent difficulty to open new landfill site and the introduction of the EU Directive 1999/31/CE with its waste reduction targets resulted in the development of new waste management strategies in Europe. The so-called “landfill directive” asks to only landfill waste after pre-treatment leading to the reduction of hazard to human and the environment. Moreover, the landfill directive also statues on a stepwise reduction of the amount of Fermentescible Organic Matter (FOM) from Municipal Solid Waste (MSW) to be landfilled. Reducing FOM in MSW going to landfill might reduce the need of landfill space and significantly diminish gas and leachate production and settlements.

Mechanical and Biological Treatment (MBT) of the residual MSW (MSW_{Res}) is a management technology to achieve this target. MBT can be developed so as to improve the sorting of recyclable materials and/or to reduce the environmental impact of landfilling associated to the anaerobic biological activity. MBT processes of MSW_{res} prior to landfilling consist of mechanical pre-processing stages followed by biological stages that reduce and stabilise the FOM under controlled anaerobic and/or aerobic condition.

The mechanical pre-processing stages are designed to treat the input with two majors objectives:

- Pre-sorting of the mixed waste for recyclable materials recovery such as glass, plastics and metals, and removal of undesirable components prior to the biological processing stages,
- Particle size fractionation and homogenisation of the waste to optimise its biodegradability during the biological pre-treatment processes.

After the mechanical pre-processing stage for waste preparation, biological pre-treatment processes are used for FOM bio-stabilisation before landfilling, in order to reduce the waste volume, the leachate and gas emission, bad odours during the waste dumping, and landfill settlements.

In 2004, in partnership with a local MSW management public organisation SDEE (Lozère France) the French Environmental Protection Agency ADEME started a research program to study the effect of MBT of MSW_{res} on their bio-physical and chemical characteristics and behaviour (settlements, leachate and biogas production) in the landfill. In this paper, the pre-treatment plant and landfill site description (site de Rédoundel, Lozère, France) are described. Then, the methodology to investigate the MBT process performance is focused on:

- Effect of MBT on waste mass reduction & bio-stabilisation,
- *Lab-scale* experiments which are set up to study the waste anaerobic biodegradation under moisture controlled conditions with or without leachate recycling,
- *in situ* leachate & biogas production, density and settlement by *in situ* monitoring of the landfill site.

2 Process description

2.1 Landfill description

The landfill consists of an entering waste control area (with a weighbridge and radioactivity detection), the MBT unit, three different landfill storage cells. One landfill cell (cell #1) is dedicated to the mixture of the maturated fine fractions (FFC1 < 50 mm + FFC2 < 70 mm) after it undergoes the MBT, the second one (cell #2) to baled waste (FIC2 50-450 mm after metal separation), and the third one (cell #1) to the waste coarse fraction (FGC1 > 450 mm). Leachate from the three cells are collected by collector wells and stored separately in three basins. A fourth basin is used to collect water from rainfalls from the “Rédoundel site“.

The MBT process currently operating at Mende has been designed to treat MSW_{Res} and to produce bio-stabilised output waste for landfilling. The description corresponds to Figure 1. The treatment plant receives residual municipal waste of Lozère, that is to say approximately 25,000 tons per annum.

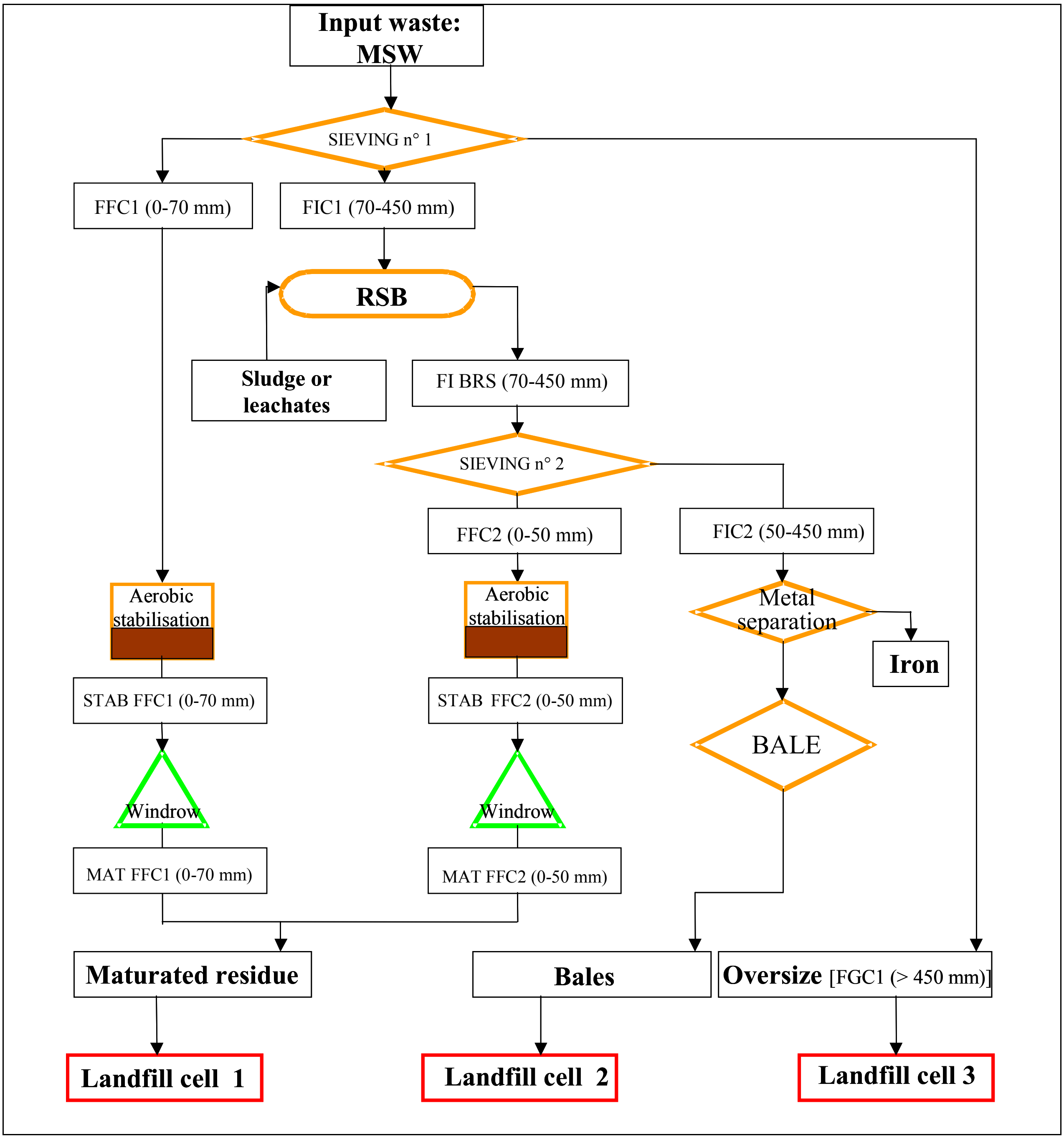

Figure 1 MBT treatment plant and landfill at Mende, Lozère, France.

2.2 Mechanical treatment and BRS

The incoming bulk Municipal Solid Wastes (MSW_{Res}) delivered to the transfer station are sent to a drum screen (trommel #1) with 70 and 450 mm diam. holes, which breaks and opens the waste bags and partially reduces the particle size. The three "size cut" are 0-70 mm, 70-450 mm and >450 mm. The screen oversize fraction (> 450 mm) is sent directly to containers and landfilled in the specific landfill cell #3. The screen undersize fraction (< 70 mm) is sent to a platform and daily feeds the stabilisation tunnels by a mechanical loader to be stabilised for 6-8 weeks. The medium fraction 70-450 mm is conveyed to a long in-vessel aerobic Rotative Sequential Bio-reactor (RSB). Biodegradation of the easily bio-degradable organic matter takes place at 60-70°C. Accelerated bio-degradation of the organic matter is supposed to be achieved in two days by the addition of sewage sludge and leachate to provide sufficient moisture for optimal biological activity. The rotation and the RSB slight angle allow the waste displacement from the inlet to the outlet. Then, the output is screened by a drum screen (trommel #2) with 50 mm diam. holes to remove materials > 50 mm. Then, this fraction mainly composed of plastics and cardboards is screened by electromagnetic separator to recover ferrous materials and, finally, baled before landfilling in the specific landfill cell #2. The size fraction < 50 mm is sent to the biological stabilisation.

2.3 Stabilisation and Maturation

The stabilisation stage (intensive composting process) of the two fine fractions FFC1 (< 50 mm) and FFC2 (< 70 mm) (see Figure 1) is carried out in open-top tunnels. The Air is passed through the waste by alternative aspiration and suction applied with underflow air vents at the basis of the windrows. The waste remains in the tunnel for 6 weeks and 8 weeks, respectively for the fractions FFC2 (< 50 mm) and FFC1 (< 70 mm). During this period, the waste is being mechanically turned and displaced two times from one tunnel to an other to promote the aeration and to reach high temperature of 70°C. The stabilisation phase produces a small quantity of leachate. After the intensive composting process, the two stabilised materials are separately sent to the outdoor platform for aerobic maturation. During the 15 weeks of the maturation phase, the windrows are neither aerated nor turned (only passive aeration), and the windrows are not covered. Leachate generated from the stabilisation and maturation stage are collected and stored on the site before being reused for the RSB. After the maturation stage, the maturated mixture of the fine fractions is landfilled in the specific landfill cell #1.

3 Process performance

3.1 MBT process performance

The MBT performance of the Mende Treatment plant is assessed by the study of the mass balance and by considering the physical, biological and chemical characteristics of the waste fractions at different steps of investigation.

3.1.1 Mass balance

The program involves waste fractions collection during two sampling campaigns performed in September 2004 and March 2005. The mass balance is established in 3 steps:

- A partial mass balance corresponding to the mechanical operations: sievings, RSB, metal separation and baling (Figure 2), where the inputs are MSW_{Res} and sludge or leachate addition in the RSB and the outputs are the two fine fractions (FFC1 and FFC2), the coarse fraction (FGC1), metals and bales.

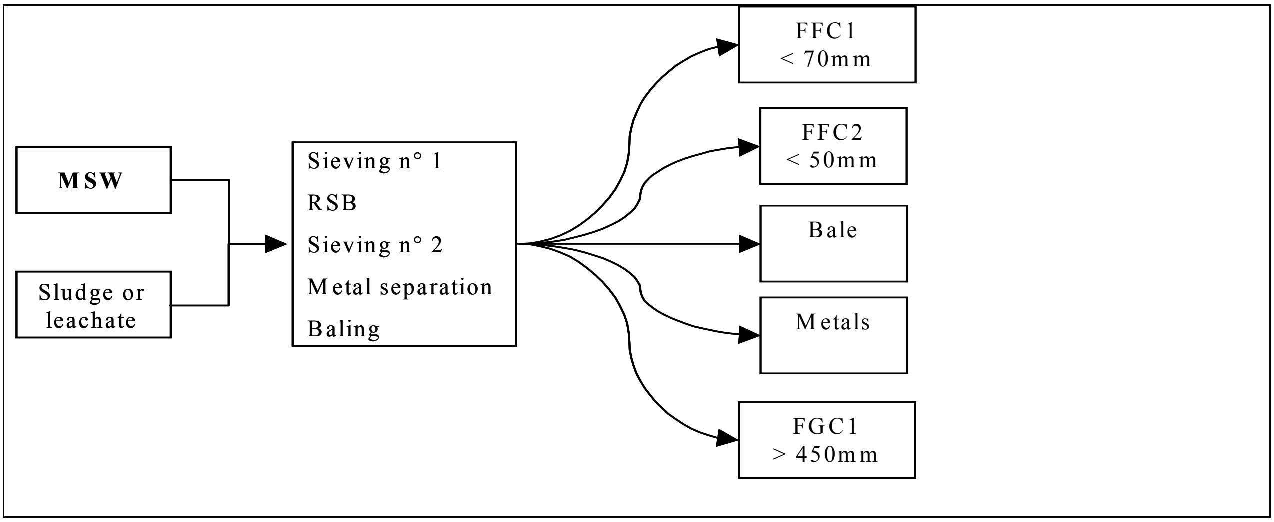

Figure 2 Partial mass balance on the mechanical operations.

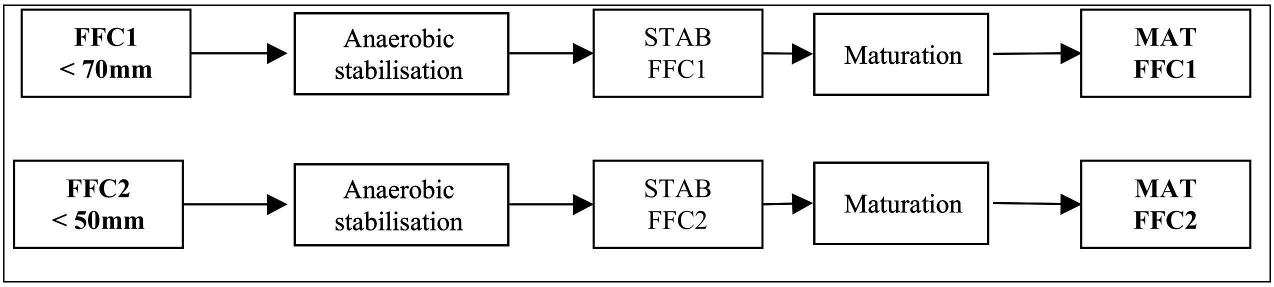

Figure 3 Partial mass balance on the biological operations.

- A partial mass balance corresponding to te biological operations: stabilisation and maturation (Figure 3), where the inputs are the two fine fractions FFC1 and FFC2 and the output are the same fractions but after the biological steps (MAT FFC1 and MAT FFC2).

- A mass balance on the whole process, where the inputs are MSW_{Res} and sludge or leachate at the outputs are the two maturated fine fractions (MAT FFC1 and MAT FFC2), the coarse fraction (FGC1), metals and bales.

To establish these mass balances, the fractions are weighed and/or sampled at different steps and different times. During each campaign (one week) only the data corresponding to the mechanical partial balance could be collected. The mass balance is expressed on the one hand as a function of wet matter and dry matter, but it is also very interesting to calculate mass reductions with regard to Dry Matter (DM), Volatile Matter (VM), Organic Carbon (OC) and Oxidative Organic Matter (OOM).

3.1.2 Solid waste analysis

The quality of MBT residues will vary as consequence of the extent of source separation and waste input, and the efficiency of the mechanical stage, BRS stage and the stabilisation-maturation stages. The program involves waste fractions collection during the two sampling campaigns performed in September 2004 and March 2005.

Biological, physical and chemical analyses will be used firstly as parameters for the evaluation of waste stabilisation during and at the end of the process and, secondly, to establish mass balance associated to the Fermentescible Organic Matter (FOM).). The physical, chemical and biological characterisation on the inlet, intermediate and outlet fraction are summarised in Table 1.

Table 1 Physical and chemical Biological waste characterisation.

Analysis	Method	Waste Fractions
Particle size characterisation	MODECOM™ (1993): 14 categories including 8 categories supposed to contain organic materials, namely fermentescible, paper, cardboards, textiles, sanitary textiles, Plastics, Combustible, Fines <20 mm, expressed in % of humid Weight (%hW) and % dry Weight (%dW).	FGC1 (> 450 mm), FIC1 (70-450 mm) FIC2 (50-450 mm) FFC1 (< 70 mm), FFC2 (< 50 mm)
Global matter analysis	Dry Matter (DM), Ignition Loss (IL=VM), Oxidative Organic Matter (OOM), Coarse Plastic Materials (CPM), Coarse Inert Materials (CIM) and Fine Inert Material <2 mm (FIM))	FGC1 (> 450 mm), FIC1 (70-450 mm) FIC2 (50-450 mm) FFC1 (< 70 mm), FFC2 (< 50 mm) Intermediate and final fraction of FFC1 (< 70 mm) & FFC2 (< 50 mm)
Elemental analysis	TOC-TIC-TC, and H, N, O, S & P (combustion methods)	FFC1 (< 70 mm), FFC2 (< 50 mm) Intermediate and final fraction of FFC1 (< 70 mm) & FFC2 (< 50 mm) during the stabilisation and the maturation process
Organic Matter biochemical analysis	- Carbohydrates (Van Soest) - Lipid Index (LI), - Protein Index (PI) - Humic Stability Index (HSI= [HA]/[FA])	
AT_{10}	Static respiration Index (aerating static condition) - Oxitop® jar test, 10 days of controlled incubation	
Self-heating capacity	Rottegrad test in Dewar bottle, 10 days of incubation	
BMP_{90}	Bio-Methanisation Potential (BMP), 90 days of incubation in anaerobic condition – 2L serum bottle.	

Waste samples are collected at different levels of the pre-treatment plant, in accordance with the MODECOM^{TM} procedure (MethODE de Caractérisation des Ordures Ménagères, 1993). Then, the collected waste fractions are characterised by several analytical methods described in details by Achour *et al.* (2005).

3.2 Lab-scale experiments

Over the last 6 months, a series of Landfill Simulation Reactors (LSR) has been conducted in order to estimate the gaseous and liquid emissions from pre-treated waste under controlled moisture condition: initial moisture control and leachate recycling or not. The leachate and biogas generation is investigated on the mixture of the untreated, stabilised and matured Fine Fractions FFC1 (< 50 mm) and FFC2 (< 70 mm). The LSR set up has been previously described (Gachet *et al.*, 2003 ; Bayard *et al.*, 2005). Six reactors were placed at a constant temperature 35 ± 1°C in a thermo-regulated chamber to stimulate mesophilic activity. Leachate flows from the container bottom into a collection vessel from where it is weekly recirculated by a peristaltic pump from the top to the bottom of the reactor. The main differences of pilot tests are presented in Table 2.

Table 2 Lab-scale experiments – operational condition.

LSR	Fraction	Leachate recycling flow	Leachate pH control
R1	Non treated mixture of fine fractions (FFC1 + FFC2) Initial moisture control (55%)*	No leachate recycling	-
R2		120 mL.kg^{-1} HW.week^{-1}	Yes
R3	Stabilised (6-8 weeks in aerating condition) mixture of FFC1 + FFC2 Initial moisture control (54.6%)	No leachate recycling	-
R4		120 mL.kg^{-1} HW.week^{-1}	No
R5	Stabilised (6-8 weeks) and maturated (15 weeks) in aerating condition) mixture of FFC1 + FFC2 Initial moisture control (47.8%)	No leachate recycling	-
R6		120 mL.kg^{-1} HW.week^{-1}	No

** Correlated to the field capacity of the waste.*

Every two weeks or month, leachate collected at the bottom of the columns is sampled and the following parameters analysed: pH, conductivity, ORP, COD, TOC-TIC-TC, NH_4^+, TKN, major anions and cations, analysed according to national or international standard procedures. Gas production and composition were monitored over the duration of the gas production period. Gas production is determined by volumetric measure (liquid phase displacement) and gas was analysed for its composition (O_2, N_2, CO_2 & CH_4) using a micro-Gas-Chromatograph, as previously detailed (Gachet, 2005).

3.3 *In situ* Landfill experiments

Monitoring of the three open landfill compartments cells consists of biogas flow rate determination with static and dynamic procedures, quantification of leachate volumes, periodic analysis of gas and leachate samples, and determination of physico-mechanical properties of dumped waste (bulk density and settlement measurement).

3.3.1 Geomechanical approach of the dumped waste

Three classes of physico-mechanical issues can be listed:

- (a) densification of waste during compacting operation,
- (b) settlements of the overall height of the waste fill,
- (c) stability problems related to the landfill slopes.

Main associated parameters are overall density ρ for (a) , compressibility ratios (primary settlement) C_R and (secondary settlement) $C_{\alpha\varepsilon}$ for (b) (Olivier *et al.*, 2005), and cohesion c and friction angle Φ characterizing the waste shear strength for (c). As far as the field case of Mende landfill is concerned, no steep and high slopes are considered, and consequently only assessment of density and compressibility ratios is carried out. More than ten real landfills of household waste were monitored by the LIRIGM in order to measure these parameters, but Mende is the first one concerning on one hand bio-mechanically pretreated material and on the other hand stacking up of bales. So the influence of the pre-treatment process will be estimated.

<u>Process for measurement of the initial density at the end of compaction</u>: Using a mechanical shovel , an amount of around V= 2.5 m^3 of pretreated waste belonging to the surface layer is excavated and weighted (humid mass M_h). The volume V is evaluated filling up the hole, previously sealed with a thin geomembrane, with a measured volume of water .The wet density after compaction is given by $\rho_h = M_h/V$. Separated assessment of the water content w allows to get the dry density $\rho_d = \rho_h/(1 + w)$. Average values $\rho_h = 1.17$ $t.m^{-3}$ and $\rho_d = 9.0$ $t.m^{-3}$ were got. These values are significantly higher than the conventional values obtained for raw domestic waste. For bales the density, obtained after dimensions measurement (volume around 1.3 m^3) is $\rho_h = 0.55$ $t.m^{-3}$.

<u>Process for measurement of the compressibility ratios:</u> The compressibility ratios are derived of the measurement of settlement at different levels along a waste vertical column (Gourc *et al.*, 2001). For the pretreated waste, the device is made of a pipe set up in a fix vertical position, founded on the bottom of the landfill before waste dumping and of several plates placed at different vertical levels during waste operation. The plates can slide along the vertical pipe, following the waste settlement. Their position is obtained by a probe using a magnetic induction system.

The values obtained for the secondary compression ratio are $0.03 < C_{\alpha\varepsilon} < 0.05$, which are closed to the lowest values for raw domestic waste. This phenomenon was expected, taking into account the high density of the refuse. For the bales stack, normal telescopic rods welded to thick metallic plates are buried in the waste mass. The top of the rod maintained above the refuse surface by successive addition of rod elements is surveyed similarly as a bench mark.

3.3.2 Leachate production and analysis

The impact of mechanical screening and biological pre-treatment on landfill leachate has been investigated on the basis of production and analysis criteria. Because of the absence of flowmeter and cumulative volume measurement, leachate production in the three independent cells is evaluated from the operating time of the pumps to evacuate leachate from the drainage layer to the leachate pre-treatment basin.

Leachate samples of the three cells were separately obtained from boreholes or pipelines frequently pumped, to avoid sampling of stagnant leachate. Leachate quality is monitored every month and sample are taken to analyse pH, conductivity, COD, BOD_5, TOC, TIC, TC, NTK, NOT, $N\text{-}NH_3$, Cr^{6+}, anions, cations and AOX.

3.3.3 Biogas production and analysis

Gaseous emission from landfills are caused by the anaerobic biodegradation of the organic matter (methanisation) and volatilisation of some organic substances initially present in the waste or generated by the biological activity. In the centre of cells, a verticale well is installed to enhance the biogas drainage. In order to determine the gas quality, *in situ* analysis under static and dynamic mode (qualitative and quantitative biogas production under controled depression and static flow measurement) have been performed and analysed by Biogas analyser GI-94 Geotechnical™ with regards to carbon dioxide (CO_2); methane (CH_4), hydrogen (H_2), oxygen (O_2) en suflur hydroxide (H_2S). Moreover, Volatile Organic Compounds (VOCs) are also analysed after trapping with tubes containing charcoal filters. The gaseous component are analysed with GS-MS.

4 Conclusion

In this paper a research program on studying a Mechanical - Biological Treatment efficiency and its consequence on MBT waste landfill behaviour has been described. Major results currently available will be presented during the symposium.

5 Acknowledgement

The authors wish to thank SDEE, Mende, Lozère, France for its technical co-operation, and ADEME (Agence Française pour l'Environnement et la Maîtrise de l'Energie) for financial support.

6 Literature

Achour, F.; de Araujo Morais, J.; Rouez, M.; de Brauer, C. Ducom, G. & Bayard, R.	2005	Characterization of organic matter in Municipal Solid Wastes: a pertinent tool for the assessment of a mechanical-biological treatment. International Symposium MBT 2005. 23-25 November 2005, Hannover, Germany.
Bayard, R. ; Gachet, C. ; Achour, F. ; de Brauer, C. & Gourdon, R.	2005	Organic matter stabilization of MSW sorted waste under simulation bioreactors. Tenth international waste management and landfill symposium, Cagliari, Italie, October 2005.
de Araujo Morais, J.; Achour, F.; Ducom, G. & Bayard, R.	2005	MBT before landfilling in France – state of the art and results of mass balance in SDEE – Mende Landfill. International Symposium MBT 2005. 23-25 November 2005, Hannover, Germany.
Gachet C., Bayard R., Singh M.K. & Gourdon R.	2003	Effects of water content and leachate recirculation on anaerobic biodegradation of landfilled waste. Ninth international waste management and landfill symposium, Cagliari, Italie, 6-10 octobre 2003 (communication orale).
Gourc,J.P.,Olivier,F.,Thomas,S.,Chatelet,L.,Deneceau,P.,Munoz,M.L.	2001	Monitoring of waste settlements on five landfills: comparison of the efficiency of different devices, Proceedings of the 8th International Landfill Symposium, Sardinia 2001, Cagliari, Italy.
MODECOM™	1993	Method for characterising household waste - 2nd Edition, Paris: ADEME Edition, 1993, 64p.
Olivier,F.,Gourc,J.P.,Coquant, C.,	2005	Predicting the storage capacity of deep landfills :Ferques bioreactor case study, Proceedings of the 10th International Landfill Symposium, Sardinia 05,Cagliari,Italy.

Author's address(es)

Dr. Rémy Bayard,

Laboratory of Environmental Analysis of Industrial Systems and Processes (LAEPSI)

National Institute of Applied Science (INSA)

20, Avenue Albert Einstein – Bâtiment Sadi Carnot

69 621 Villeurbanne Cedex France

Phone +33 472 43 87 53 remy.bayard@inso-lyon.fr