Characterization of organic matter in Municipal Solid Wastes: a pertinent tool for the assessment of a mechanical-biological treatment.

Faouzia ACHOUR ; Joacio de ARAUJO MORAIS ; Maxim ROUEZ ; Christine de BRAUER ; Gaëlle DUCOM , Remy BAYARD

Laboratory of Environmental Analysis of Industrial Systems and Processes (LAEPSI); National Institute of Applied Science (INSA) Lyon France

Abstract

A methodology of characterization of organic matter was developed and applied to assess the efficiency of a mechanical and biological pre-treatment (MBT) performed on a landfill site at Mende (France). It is based on chemical and biological tests. The comparison of the results at different steps of the process underlines the impact of the MBT on the stabilization of the organic matter (OM). This work allows identifying the more pertinent tests for the assessment of the organic matter stability.

Keywords

Mechanical-biological waste pre-treatment, stability of organic matter

1 Introduction

The aim of the work is to compare potential biodegradability of waste at different steps of the MBT in order to measure its impact.The pre-treatment at Mende consists in two screenings followed by biological treatments. The first screening (S1) separate the waste in three fractions: a coarse fraction (CFS1> 450 mm), a fine fraction (FFS1<70 mm) and an intermediate fraction (IFS1 70-450 mm). The IFS1 is treated in the Rotating Sequentiel Bioreactor (RSB). At the outlet of the RSB, a second screening (S2), separate (IFS1) in two fractions: an intermediate and a fine fraction (IFS2 > 50 mm), (FFS2<50 mm). Fine fractions FFS1 and FFS2 undergo an aerobic stabilization during 6 weeks followed by a 12 weeks long maturation phase. During the stabilization phase, waste is turned over once, at 3 weeks, for FFS1 and twice, at 2 and 4 weeks, for FFS2 in order to allow a better aeration.

Based on the literature methods used in the study of organic matter (OM) in all kinds of materials (soils, composts, sediments....) a characterization methodology was implemented. It was managed at different levels:

- at first, the global characterization includes the sorting of wastes according to composition and nature using the MODECOM™ procedure [AFNOR XPX 30408, 1993], the determination of Ignition Loss (IL), and of the Oxydizable Organic Matter (OOM).

- the chemical characterization consists in measuring the contents in humic substances, lipids and proteins.
- the biological characterization is founded on an anaerobic biodegradation test to determine the Bio-Methanation Potential (BMP), an aerobic biodegradation test to determine the Respiratory Activity in Static condition at 10 days (RAS_{10} test), and a self-heating capacity test (Rottegrad).

2 Materials and methods

2.1 Waste sampling

The steps of the mechanical and biological treatments are described in figure 1, where acronyms of the different fractions are specified.

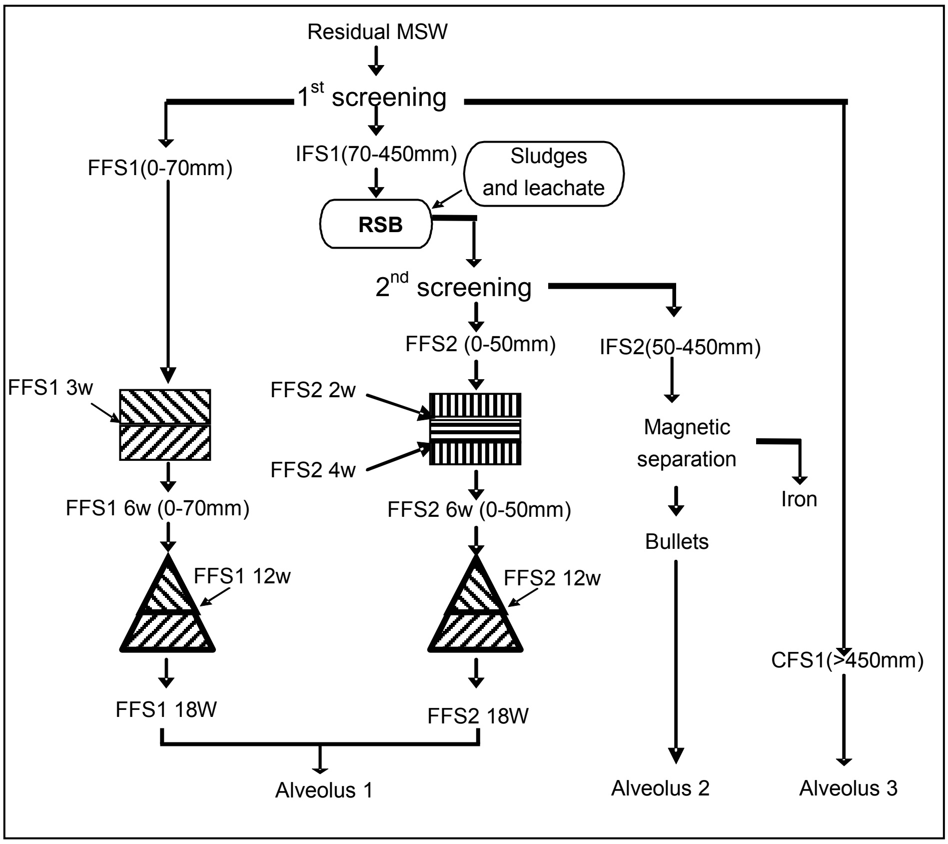

Figure 1 MSW pre-preparation in Mende plant

2.2 Global Characterization

MODECOM^{TM}: this procedure is applied to sort the wastes into 13 categories. However some of them have been gathered on the criterion of their biodegradability. Thus, the four categories without organics are mustered in "inert matter" (IM). The plastic and composite wastes form the PCM class. Papers, paperboard, and textiles form PB group.

The fourth category called FE is constituted by the fine elements (<20mm). The last family is that of fermentescibles (FER).

Ignition Loss: ignition loss (IL) is evaluated according to the French Standard gravimetric procedure [AFNOR NF U-44-160, 1985].

Oxydizable Organic Matter (OOM test): The oxidizable fraction is evaluated according to the french standard procedure [AFNOR NF XPU 44-164, 2004]. This gravimetric method consists in a total chemical oxidation by concentrated NaClO. The solid residue is separated, dried and divided in three fractions: Coarse Plastic Material (CPM) > 2 mm, Coarse Inert Material (CIM) > 2 mm and Fine Inert Material (FIM) < 2 mm. Finally, OOM is estimated by the difference: OOM = Total Solid Matter – RPM – RIM – FIM.

2.3 Chemical characterization

Lipid Index (LI) (ACHOUR, 2004): Hydrophobic compounds were extracted at 20°C, using a 50-50% heptane-ethanol mixture. The solvent was removed in a rotary evaporator and the solid residue dried at 60°C before weighting.

Protein Index (PI) was determined by indirect quantification of organic nitrogen N_{org} by TKN (Total Kjeldhal Nitogen) and mineral nitrogen $N_{mineral}$ analysis. Protein Index is calculated from: $PI = N_{org} \times 6.25$, where $N_{org} = TKN - N_{mineral}$ (DIGNAC, 1998).

Humification Index (HI): The acido-alkaline extraction method (FRANCOU, 2003) was used to quantify humic substances by measuring Total Organic Carbon (TOC) content in the solutions Humic Acid (HA) and Fulvic Acid (FA) were solubilized using NaOH (pH 12). After centrifugation the analysis of the supernatant leads to $[TOC]_{HA+FA}$. The supernatant was then acidified to pH 1.5 with concentrated H_2SO_4 in order to precipitate HA. The Total Organic Carbon of the liquid is $[TOC]_{HA}$. Finally, the humic index is calculated from $HI = [TOC]_{HA}/[TOC]_{FA}$ where $[TOC]_{HA} = [TOC]_{HA+FA} - [TOC]_{FA}$).

2.4 Biological characterization

BioMethane Potential (BMP): was determined according to standard procedure (ISO 11734, 1995). The inoculum was a methanogenic population previously cultivated from digester sludge under mesophilic conditions (35°C). The gas production was monitored by pressure measurement all along the incubation.

Self heating capacity: This parameter was determined by the Rottegrad test (protocol of the German federal association on the quality of the compost – BGK –1994). It gives information about the maturity of the waste through the highest temperature (Tmax) measured in the waste during 10 days of incubation at ambient temperature (20°C). The following stability scale is used: degree I (60 <Tmax <70°C coarse matter), degree II (50

<Tmax <60°C fresh matter), Degree III (40 <Tmax <50°C fresh matter), degree IV (30 <Tmax <40°C stabilized matter), Degree V (20 <Tmax <30°C very stabilized matter).

RAS_{10} test: The protocol of Respiratory activity in Static condition (RAS_{10}) is based on the procedure AT4, of the reference test of the German decree on the storage of the pre-treated waste. In the RAS_{10} test, the oxygen consumption at 20°C is followed for 10 days instead of 4 days in AT4 test.

3 Results and discussion

3.1 Characterization of fractions coming from screenings

Figure 2 shows that screenings gather the fine elements (FE <20 mm) in the FFS1 and FFS2 fractions (58% and 82% respectively). The intermediate and coarse fractions are richer in PB and PCM categories.

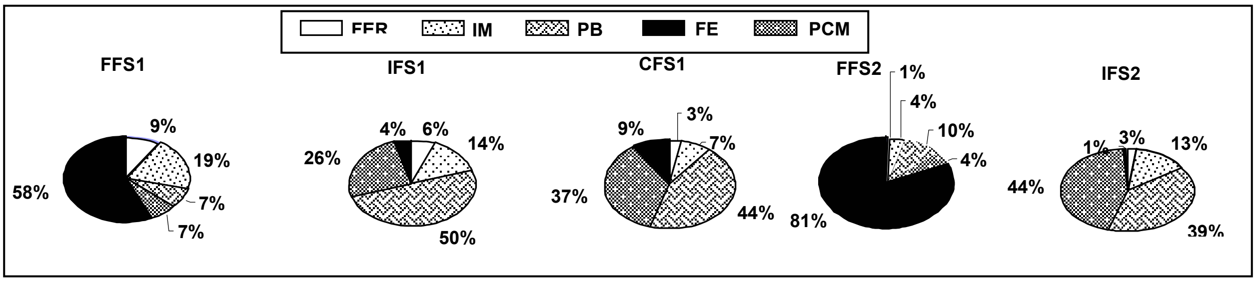

Figure 2 Characterization of fractions coming from screenings according to MODECOM

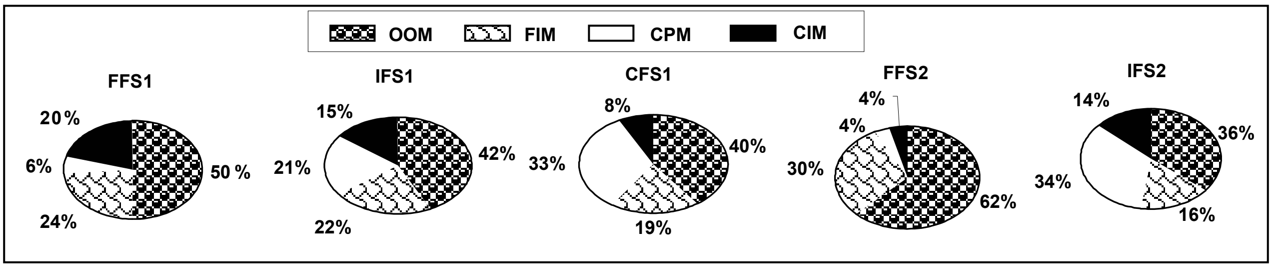

Figure 3 Characterization of fractions coming from screenings according to OOM test.

Fractionation according to OOM test (figure 3) shows that the fine fractions of both screenings exhibit higher OOM content while intermediate and coarse fractions are principally composed of plastics.

The figure 4 compares IL and OOM contents of all of the studied fractions. IL is clearly higher than OOM for all the fractions with the exception of FFS1. The gaps between the IL and OOM are not surprising because the ignition conditions allow volatilizing all of the organic matter including plastics, while chemical oxidation preserves these synthetic materials and only degrade natural organic matter. As plastics are not biodegradable the biodegradability of the waste is thus better evaluated by OOM than by Ignition Loss.

The very low plastic content of FFS1 (figures 2 and 3) leads to similar IL and OOM parameters. The higher OOM percentage of FFS2 fraction compared to FFS1 is reliable to its high FE content (figure 3) because this category groups all sort of wastes with a high proportion of food and green wastes that increase the OOM of the FFS2.

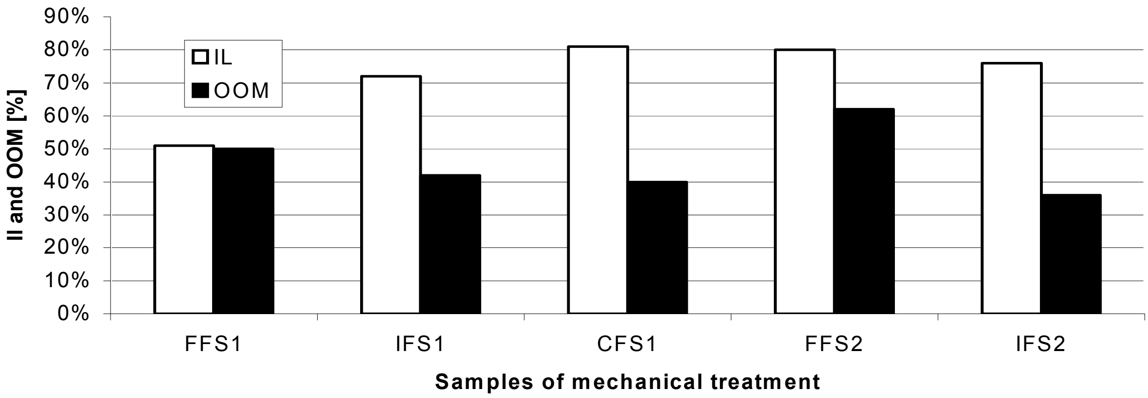

Figure 4 Comparison of the IL and OOM of the fractions coming from screenings

3.2 Characterization of fine fractions during biological treatment

3.2.1 Estimation of the ignition loss of the fine fractions

Table 1 shows the abattement of IL all along the steps of the biological treatment. The abattement of FFS1 becomes practically unperceivable beyond the three first weeks. At the end of the maturation phase the abattement is 13 %.

Table 1 Abattement of IL and OOM of the fine fractions during biological treatment

	[%] abattement = ($IL_{initial}$ - IL) / $IL_{initial}$)	**[%] abattement = ($OOM_{initial}$ - OOM) / $OOM_{initial}$)**
FFS1 3w	12.6 %	15.5 %
FFS1 6w	13.2 %	15.0 %
FFS1 12w	12.8 %	19.5 %
FFS1 18W	13.2 %	29.5 %
FFS2 2w	7.1 %	23.6 %
FFS2 4w	8.7 %	29.3 %
FFS2 6w	19.1 %	32.6 %
FFS2 ½M	18.8 %	43.6 %
FFS2 18W	22.1 %	58.2 %

The IL abattements of FFS2 fractions uniformly increase until to attain 22% at the end of the process. The FFS2 fraction evolves more quickly than the FFS1 fraction.

3.2.2 Estimation of the OOM of the fine fractions

At the end of the maturation step, the OOM abattement of the FFS2 fraction attains to 58%, while the final abattement of FFS1 is only 30%. This result confirms that the FFS2 fraction is more biodegradable than FFS1. The strong proportion of FE (81%) in FFS2, and the adds of leachate and sludges in RSB favor the development of microorganisms and contribute to accelerate the degradation of FFS2.

3.3 Bio-chemical Characterization of the OM in the fine fractions

3.3.1 Lipids Index and Protein Index

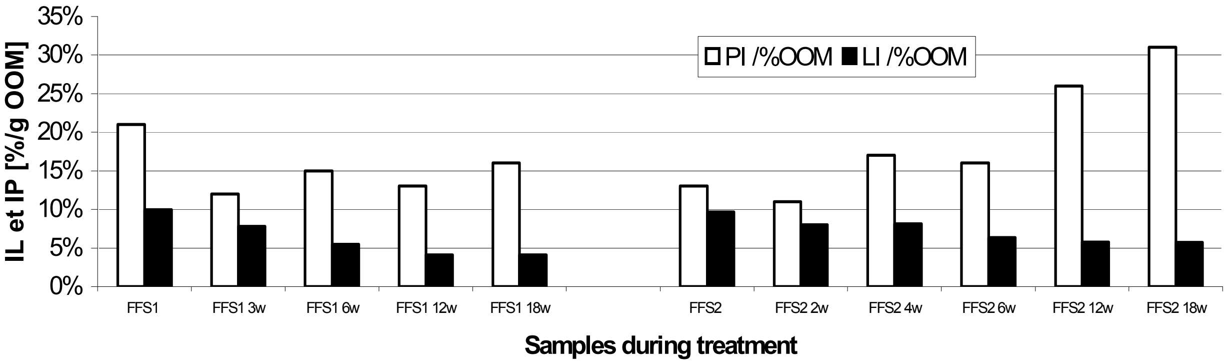

Figure 5 Evolution of the lipid and protein index throughout the pre-treatment

Lipids are considered as easily biodegradable compounds. As shown on figure 5, the lipid index decreases throughout the biological pre-treatment of FFS1 and FFS2. On the other hand, FFS1 protein index progressively diminishes while FFS2 protein index decreases in the earlier phase of treatment and increases at the end of the process.

3.3.2 Fractionation in humic substances

The stabilization of the wastes was evaluated through the Humification Index. This parameter increases with the proportion of polymerised organic matter to reach a value of HI = 1 when materials are stabilized (ROLETTO, 1985). HI increases but remains inferior to 1 for all the fractions coming from the first screening (table 2). In spite of a lower humification index than FFS1 at the beginning of the process, the FFS2 fraction exhibits an humification index superior to 1 at the end of the treatment. This result indicates that the FFS2 fraction is better stabilized.

Table 2 Humification Index COT_{AH}/COT_{AF}, of fine fractions throughout the pre-treatment

Sample	COT_{AH}/COT_{AF}	Sample	COT_{AH}/COT_{AF}	Sample	COT_{AH}/COT_{AF}
FFS1	0.34	FFS1 18W	0.64	FFS1 6w	0.55
FFS1 3w	0.40	FFS2	0.12	FFS2 12w	0.97
FFS1 6w	0.43	FFS2 2w	0.28	FFS1 18W	1.05
FFS1 12w	0.65	FFS2 4w	0.29		

3.4 Biological Analysis of the fine fractions

3.4.1 Bio-Methane Potential (BMP)

Figure 6 shows the cumulative biogas production of fine fractions. The BMP test duration is 120 days but experimental results about FFS 12w and FFS 18w fractions are not yet available beyond the 46 first days. An important decrease of the cumulative biogas production is observed during the aerobic treatment of FFS2. This tendency is not so evident for FFS1 because the gas production not evolves a lot beyond the third week of biological pre-treatment. Moreover, all of the FFS1 samples do not produce anymore biogas after 90 days of incubation. The quantities of gas produced by FFS2 fractions that did not undergo the last phase of maturation are higher than those measured for all of the FFS1 fractions. The FFS2 fractions collected during and after the maturation phase produce few quantities of biogas and behave like FFS1 fractions collected on and after the third week of the biological treatment. These results indicate that FFS2 is more biodegraded and are coherent with the conclusions of biochemical characterization.

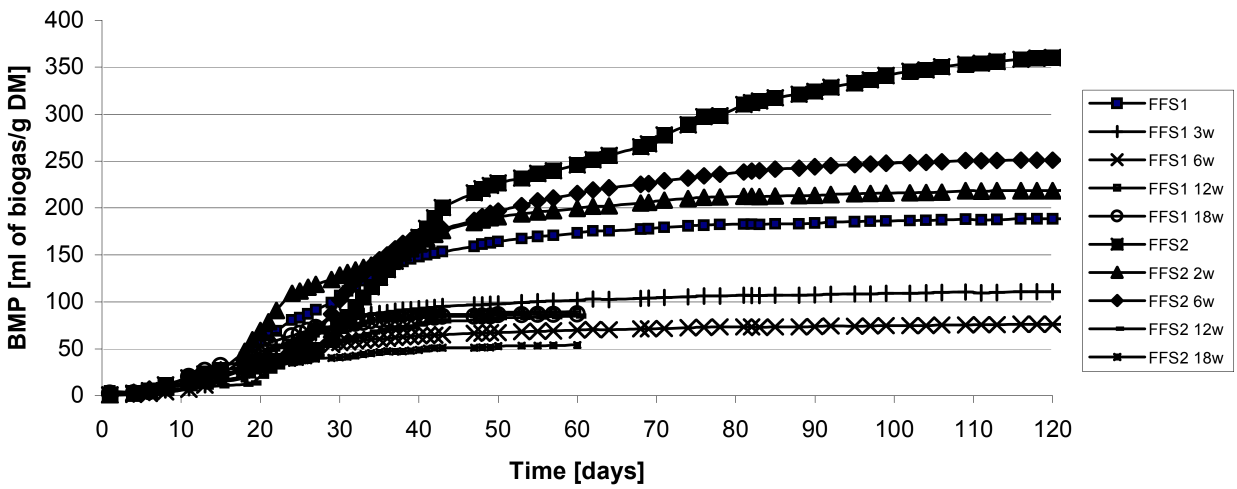

Figure 6 Cumulative biogas production of the fine fractions

3.4.2 Self heating capacity of the fine fractions

Results from Rottegrad test are shown on figure 7. Untill the end of stabilization phase all the fractions are classified as coarse matter (degree I). The fraction FFC2 1/2M is considered as fresh matter (degree III). FFC1 1/2M, FFC1 M and FFC2 M are identified as stable matter (degree IV). This test does not seem to be as pertinent as the BMP test or the chemical characterization to evaluate the degree of maturity of the FFS1 and FFS2 fractions.

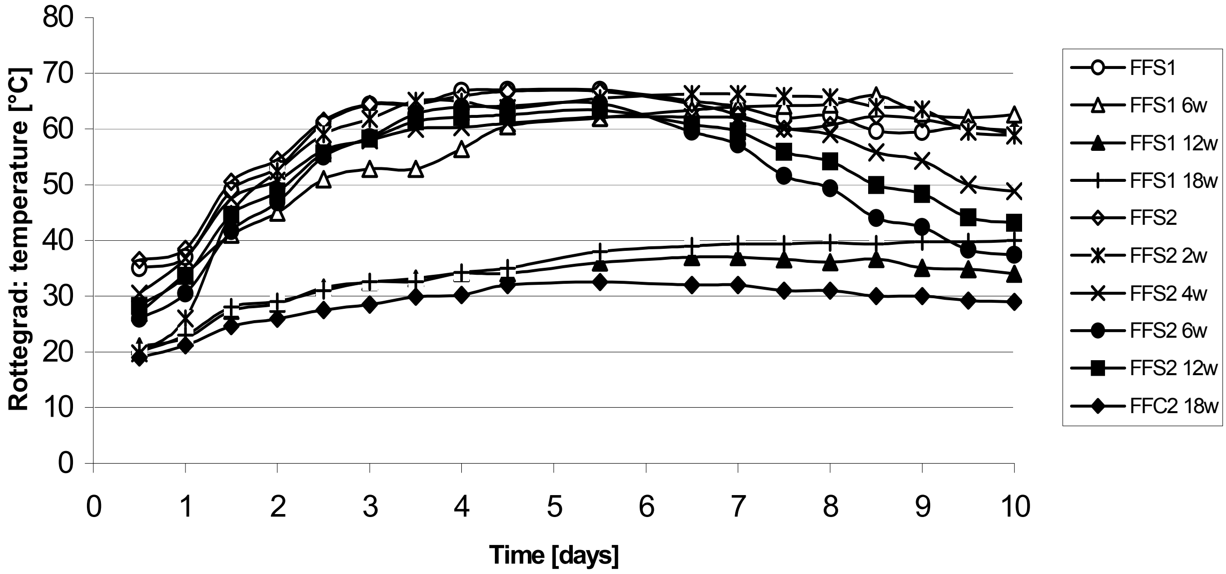

Figure 7 Rottegrad Test of the fine fractions

3.4.3 Respiratory Activity in Static condition

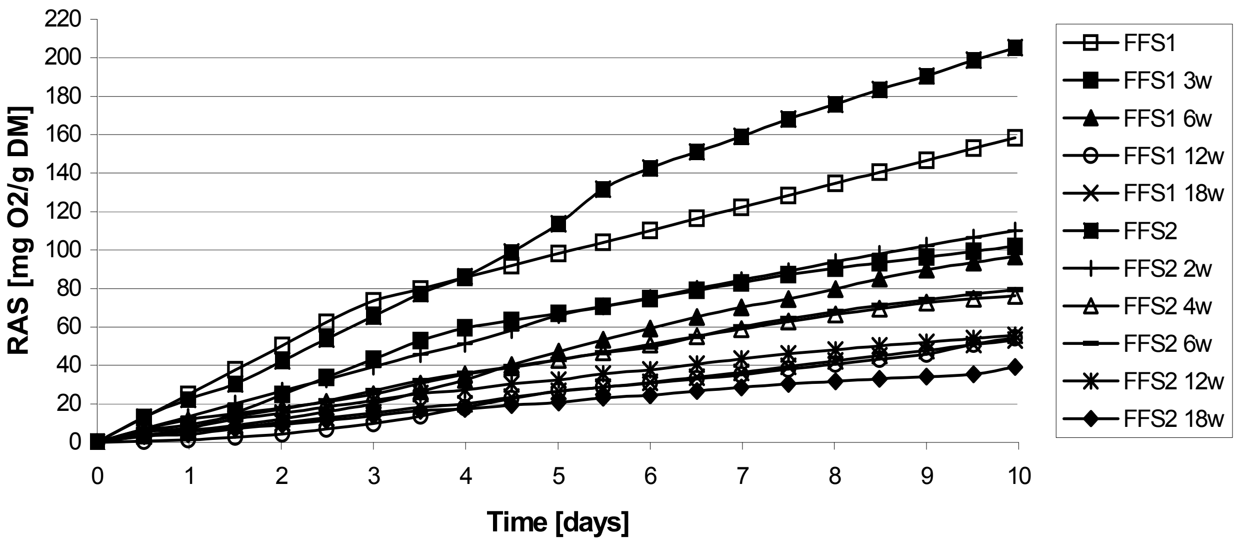

Figure 8 RAS_{10} test of the fine fractions

Figures 8 shows the results of the RAS_{10} test for FFS1 and FFS2 fractions. In both cases, the coarse fractions present high activities. RAS_{10} is 160 mg $O_2.g^{-1}$ DM for FFS1 fraction and 210 mg $O_2.g^{-1}$ MS for FFS2. These values show that FFS1 is less biodegradable than FFS2 in aerobic conditions. As expected, the RAS_{10} diminishes throughout the aerobic treatment of both fractions. Nevertheless, FFS1 12w and FFS1 18w have the same RAS_{10} just like FFS2 4w and FFS2 6w.

4 Conclusion

The extent of waste maturation is usually assessed with regard to the level of biological activity by the mean of microbiological tests. In this work, this biological approach including BMP, Rottegrad and RAS_{10} tests, is completed by a chemical investigation though the determination of ignition loss, oxidizable organic matter, lipid and protein contents, humic index and finally by a matter characterization using the MODECOM™ procedure. This methodology, applied to samples collected at each step of the mechanical and biological pre-treatment (MBT) performed on Mende's landfill site, allowed to demonstrate its efficiency. The comparison of the two methods leads to the identification of the more pertinent tools to assess the organic matter degree of stability. The MODECOM™ sorting procedure and the chemical oxidation (OOM test) appear to be the more effective ways of quantifying the biodegradable organic matter. The humic index gives a good idea of the waste degree of maturity. The lipid index, that progressively decrease during the pre-treatment and particularly the protein index are not so easily readable. In-depth investigations of the evolution of these parameters throughout the maturation process are necessary. Finally, the Rottegrad test does not seem to be as pertinent as the BMP test or the chemical characterization to evaluate the degree of maturity of the different fractions.

5 Literature

AFNOR NF XPU 44-164	2004	Amendements organiques et supports de culture Méthode d'analyse des composants inertes dans un compost. AFNOR Editions, Paris, France.
AFNOR XPX 30 408	1993	A method for characterization of domestic waste AFNOR Editions, Paris, France.
AFNOR NF U-44-160	1985	Amendements organiques et supports de culture Détermination de la matière organique totale- Méthode par calcination. Matières fertilisantes et supports de cultures. AFNOR Editions, Paris, France.

ACHOUR, F.	2004	Caractérisation de la matière organique dans les ordures ménagères. MSc dissertation, LAEPSI Laboratory, INSA de Lyon, France, 65 p.
Dignac, M. F.	1998	caractérisation chimique de la matière organique au cours du traitement des eaux usées par boues activées. PhD dissertation Université Paris VI.
Francou, C.	2003	Stabilisation de la matière organique au cours du compostage de déchets urbains : Influence de la nature des déchets et du procédé de compostage-Recherche d'indicateurs pertinents. PhD dissertation. Institut National Agronomique Paris-Grignon, 287 p.
ISO 11734	1995	Water quality - Evaluation of the "ultimate" anaerobic biodegradability of organic compounds in digested sludge – Method by measurement of the biogas production.
MODECOM™	1993	Method for characterising household waste - 2nd Edition, Paris: ADEME
Roletto, R. Barberis, R. Consiglio, M. Jodice, R.	1985	Chemical parameters for evaluing compost maturity. Biocycle, 26 pp 46-47.

Author's address(es)

Phd. Faouzia Achour
Laboratory of Environmental Analysis of Industrial Systems and Processes (LAEPSI); National Institute of Applied Science (INSA)

20, av. Albert Einstein,
69621 Villeurbanne Cedex
France
Phone +33 472 43 70 26
Email faouzia.achour@insa-lyon.fr
Website: www.insa-lyon.fr