‘Mechanical-Biological Treatment: the French approach to agronomic compost quality’

How to generate soil conditioners from RHR* in order to optimise the recovery of organic matter

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Summary

The French Urban Waste Treatment Market is characterised today by the growing development of Mechanical-Biological Treatment (MBT) plants producing premium quality compost recycled to land. In that scheme, Urban Domestic waste collected at the kerbside (after selective collection of glass, tin and aluminium cans, batteries, etc.) either undergoes aerobic composting or anaerobic digestion (followed by secondary composting in accordance with French Standard NFU 44051 for organic fertiliser substances) to produce top quality compost for agricultural recycling.

In 2008, over 10% of the 50 million tons of urban waste were transformed in 30 MBT plants into approximately 3 million tons of standardised compost currently being recycled in agricultural fields.

This paper will describe and analyse the current status of French MBT plants on a technical basis, providing the regulatory framework for compost management. Various issues will be addressed (partnership between waste processors and downstream compost users, the type of MBT technology implemented, flow sheets, etc.) and special emphasis will be placed on the environmental benefits of the MBT approach.

* *Residual Household Refuse*

1 Introduction: the French background to the mechanical-biological treatment of waste

1.1 Terminology

While, at present, there is no statutory definition relating to the mechanical-biological treatment of urban domestic waste in France, the concept of MBT is now frequently used to denote the new generation of aerobic composting plants, with or without methanogenesis (anaerobic digestion, AD), which converts residual household refuse (RHR) into fertiliser substances, plus a potential renewable energy outcome with biogas produced under AD conditions.

As far as technicians are concerned, the MBT plants – ranging from small composting units to large factories such as Lille or Montpellier, which produce electricity and soon vehicle fuels - are a measure of the continuous advancement in the fermentation of refuse, reflected in more than 3 centuries of technological progress.

The concept of residual household refuse (RHR) relates to domestic waste considered without selective collection of biowaste on a door-to-door basis (kitchen waste, vegetable waste) and in conjunction with the collection of toxic waste in diverse quantities (batteries, chemical products, etc,) via a dedicated network (waste collection centres, voluntary deposit points, etc.).

This last condition is not the less important one as it represents a major guaranty for compost quality and toxic contamination by heavy metal, dangerous chemicals etc.

1.2 The French statutory framework governing the treatment & recycling to land of organic waste

Major driving force of the waste management market, the statutory framework governing the management of recycled organic waste in agriculture applies at two main levels:

- on the one hand, the level of Classified Installations for Protection of the Environment (CIPE), with technical constraints and requirements developed in order to restrict their nuisance impact (mainly odours emissions)
- and, on the other hand, in terms of the quality of the organic soil conditioning products, under application of the provisions of the Code Rural which, by means of industrial standards, imposes thresholds for various analytical parameters.

Under pressure from the European Community in particular, this national framework is subject to periodic change.

Thus, the recent revised French Standard NFU 44-051 relating to organic soil conditioners, put into force by the Decree dated 21 August 2007 (Official Journal dated 28 August 2007), is to be applied to all domestic waste composting plants with effect from 1st March 2009.

Moreover, the 50 or so older sorting/composting plants, with upstream crushing, constructed or refurbished[1] during the 1980s, no longer comply with the regulations and, in

[1] Les Résidus ménagers : Composition, collecte et traitement, André Saurin Ed. Eyrolles (1967), 80p

turn, are no longer capable of producing standardised soil conditioner for use in agriculture[2].

1.3 The impact of the revised Standard NFU 44-051 on MBT plants

While the revised Standard NFU 44-051 does not exclude the production of organic soil conditioner from RHR[3], it nonetheless stipulates **obligations regarding results** (and not methods) with regard to:

- agronomic parameters
- the content and throughput of metallic trace elements (MTE) and polyaromatic hydrocarbons (PAH)
- and the maximum content of undesirable/inert substances and pathogenic agents (salmonella, whipworms).

It appears that this *'French form of MBT'*, operated on RHR, constitutes an exception within the Community landscape, together with Spain and the United Kingdom (not mentioning Canada).

As a matter of interest, in spite of some opposition exclusively in favour of the selective door-to-door collection of biowaste, French regulations permit the production of fertiliser products derived from RHR.

Indeed, various trial investigations conducted on an industrial scale (for example the Launay Lantic plant in Brittany) have demonstrated the technical feasibility of the standardised production of compost from RHR.

Finally, by applying Community objectives to the recycling of waste, France has declared its intention to maximise the rate of collection of organic matter[4] (OM) in the RHR in order to favour organic recycling.

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[2] The Circular dated 27/02/09 only authorises interim manure spreading plans and – in the final analysis – depositing in landfill at a storage centre.

[3] The term 'RHR' relates to residual waste (grey rubbish bin) after the collection(s) of dry recyclable materials (iron and steel, aluminium, plastic bottles, packaging) and special domestic waste (dry cell batteries, vehicle batteries, medicines, etc.) and, in some cases, green waste.

[4] 'Biodegradable organic matter' comprises the non-synthetic organic matter contained in the waste. 90% of the non-biodegradable or synthetic matter is plastics, which represents a 10% ash content (source: CEMAGREF).

At the moment, the mechanical-biological treatment of RHR with the production of soil conditioner is experiencing a significant revival of interest on the part of numerous French contracting authorities.

At the end of 2008, the ADEME (Agence de l'Environnement et de la Maitrise de l'Energie *[the French Environment and Energy Conservation Agency]*) listed some 40 projects (50-50 for new sites and upgraded facilities) between now and 2012, totalling an annual flux of 3 million tonnes of waste.

2 Recycling organic matter and typology of the mechanical-biological treatment systems

2.1 Strategies for recycling residual organic matter

Management of the organic content of residual refuse, which may contain up to 50% biodegradable organic matter, is based on 2 separate approaches:

- Approach 1: selective collection of biowaste with the implementation of two specific treatment processes, one applied to the biowaste in order to produce a soil conditioner (aerobic composting or anaerobic digestion) and the other applied to the residual portion of the RHR in order to 'economise on landfill capacity'
- Approach 2: Non-selective collection of biowaste with the implementation of Mechanical-Biological Treatment of the RHR, together with the production of an organic soil conditioner (aerobic or anaerobic treatment)

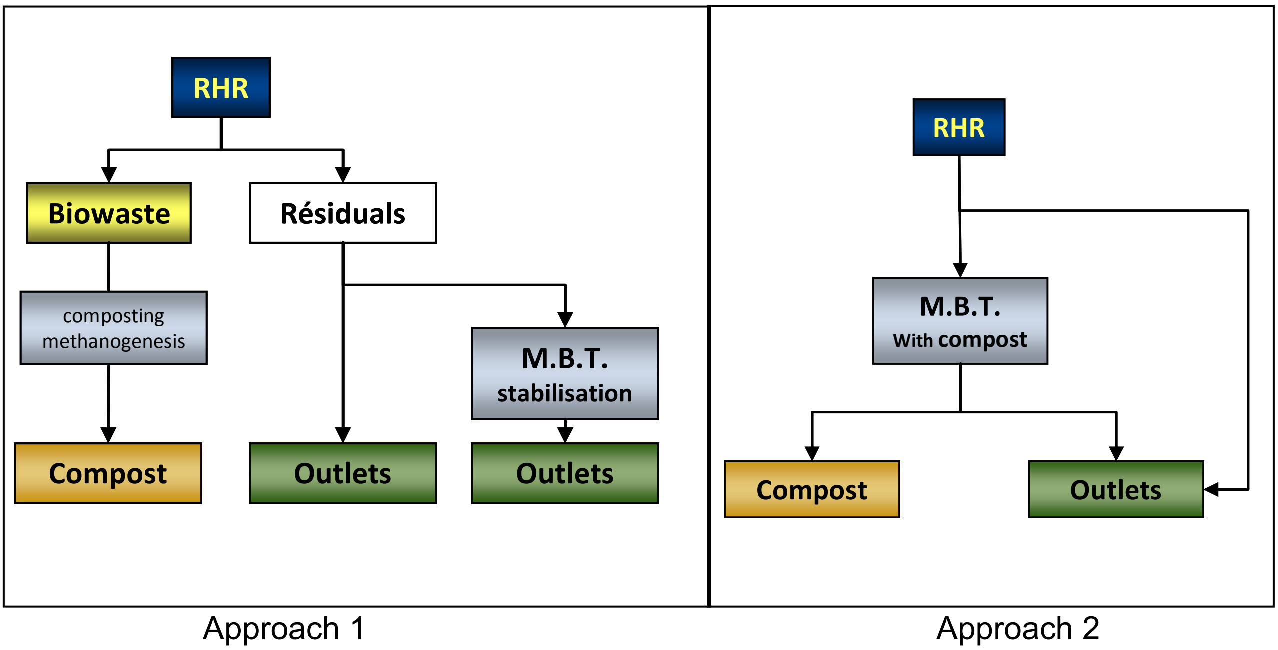

Figure 1: Typology of managing pathways of the organic matter of RHR

The outlets consist of landfill installations for non-hazardous waste (ISDND) or incinerators, which also generate a proportion of final and hazardous waste which must be buried as landfill.

In the case of Approach 2, which is the subject of this analysis, Figure 2 (below) illustrates the sequence of treatment operations, including an optional anaerobic stage.

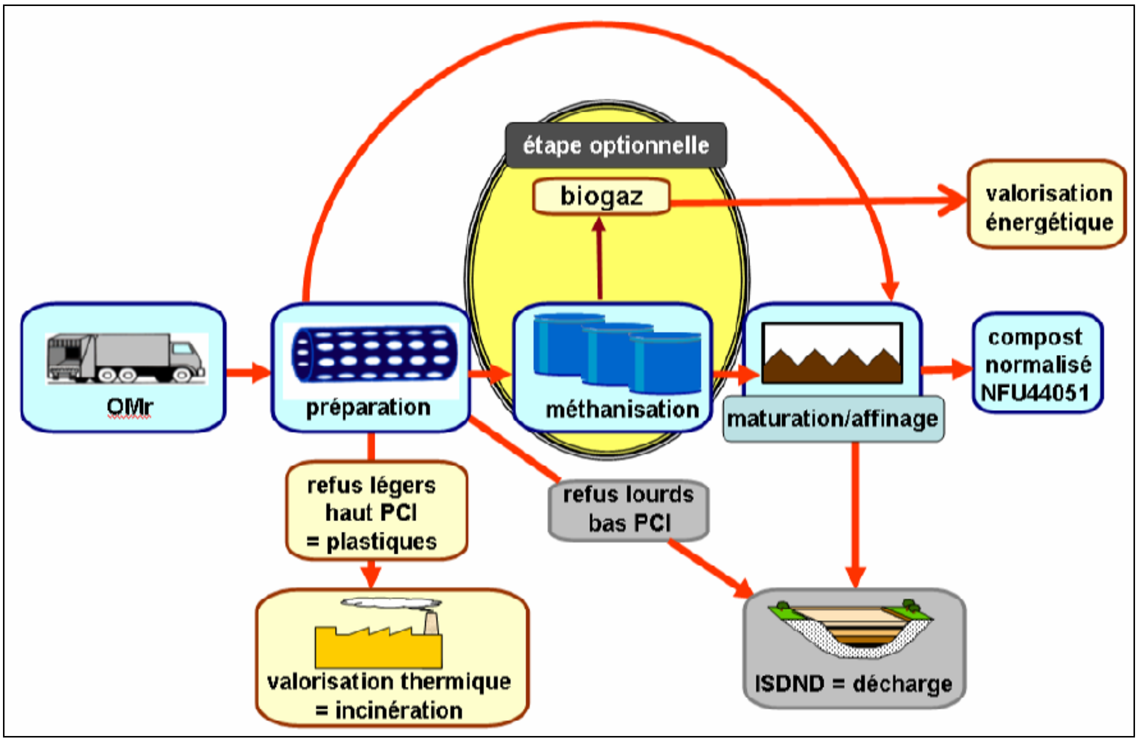

Figure 2: Schematic diagram of the MBT process applied to RHR (with optional methanogenesis)

2.2 Performance of selective collection of organic matter schemes

Based on a recent study for the ADEME (2008) conducted on 65 operations involving the selective collection of fermentable substances in France[5], the returns appeared to be relatively mixed, with low collected throughput characterised by, among other factors, an average quality since, to a major extent, they consisted of garden waste.

[5] Technical-economic analysis of the operations involving the biological management of waste, ADEME, May 2008. A summary can be viewed at: http://www2.ademe.fr/servlet/getBin?name=44CE7B751FC5359964C4B3A7358672E61232632467701.pdf

Indeed, as shown in Table 1 (below), this study highlighted collection rates for biowaste of between 44 kg/occupant/year[6] and 94 kg gross/occupant/year[7].

Table 1 : Summary of the results of the rate of collection of biowaste in France (2008 – ADEME)

	Type of collection analysed		**Total**
	Type 1	**Type 2**	
No. of operations	30	35	65
Type of biowaste	Kitchen waste	Kitchen waste + Garden waste	
Tonnage 2005	30,898	136,153	167,051
Average quantity	44 kg/occupant/year	94 kg/occupant/year	78 kg/occupant/year

It should be noted that, in France, due to the number of operational composting plants[8], the treatment of garden waste does not present any particular problem.

Furthermore, there is evidence of significant sensitivity on the part of methanogenesis processes to the seasonal variations of garden waste, with impacts on the quantity as well as the quality of the source materials.

Since they usually operate on a continuous basis (whereas composting is generally performed in batches), methanogenesis plants are subjected to variations in the quality of source materials being fed to the reactor.

Because stability is required for the process, those fluctuations in quality with not readily compatible waste are more than likely to face operational difficulties.

In view of the 65% humidity content, the volume of biodegradable organic matter 'recovered' by the observed selective collection procedures is therefore of the order of **15 kg dry matter/inhabitant/year** (excluding garden waste); this is very low and calls into question the economic viability of this type of arrangement in France.

2.3 Effectiveness of MBT plants

In view of the disappointing results obtained from the selective collection of organic matter in France, the opportunity of producing soil conditioners derived from RHR repre-

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[6] Ratio obtained for the sole specific collection of kitchen waste

[7] Ratio obtained during the combined collection of kitchen waste and garden waste

[8] http://www.orgaterre.org/presentation-audit-compostage-6-pages.pdf

sents a solution for developing the rate of recovery of biodegradable organic matter in RHR, in terms of both kitchen waste and paper/cardboard.

The operational units and the currently-planned MBT units with the production of soil conditioner are intended, on average, to guarantee a rate of recovery of biodegradable organic matter of the order of 90 kg gross/occupant/year[9], compared with 44 kg gross/occupant/year for the collection of biowaste (excluding garden waste).

However, it should be emphasised that compliance with the threshold imposed by the Standard NFU 44-051 requires the implementation of a series of stages of mechanical-biological treatment which are relatively complex and cumbersome, particularly in view of the multiplicity of non-synthetic organic matter in the RHR and the undesirable substances which have to be removed.

3 The type of biodegradable organic matter in residual household refuse and the potential for recovery

3.1 Fractional analysis of the average residual rubbish in France

Recent analyses of grey (residual) rubbish bins have highlighted the significant uniformity of the materials in the rubbish, associated with major variations in terms of the size (granulometry) of the ‘constituent categories’.

[9] In relation to dry matter, the recovery values for organic matter derived from RHR are even more favourable for MBT projects.

Table 2: Example of the composition of a typical batch of RHR

Categories	Typical composition (as % dry)
Fermentable substances	11.0
Paper	18.0
Cardboard	8.8
Composites	2.3
Textiles	2.3
Sanitary textiles	6.6
Plastic films	5.4
Plastics	8.7
Unclassified combustible substances	4.3
Glass	7.8
Ferrous metals	4.0
Other metals	0.8
Unclassified non-combustible substances	4.7
Special waste	0.9
Fine particles <8 mm	14.4
	100.0

Table 2 shows, for a series of communities, the average typical composition of the residual rubbish, drawn up on the basis of 15 designations of the MODECOM® method developed by the ADEME in France:

Illustrating the variability of the characteristics of the aforementioned categories, Figure 2 represents a typical granulometric distribution of the various constituent categories of RHR (with the exception of fine particles <8 mm):

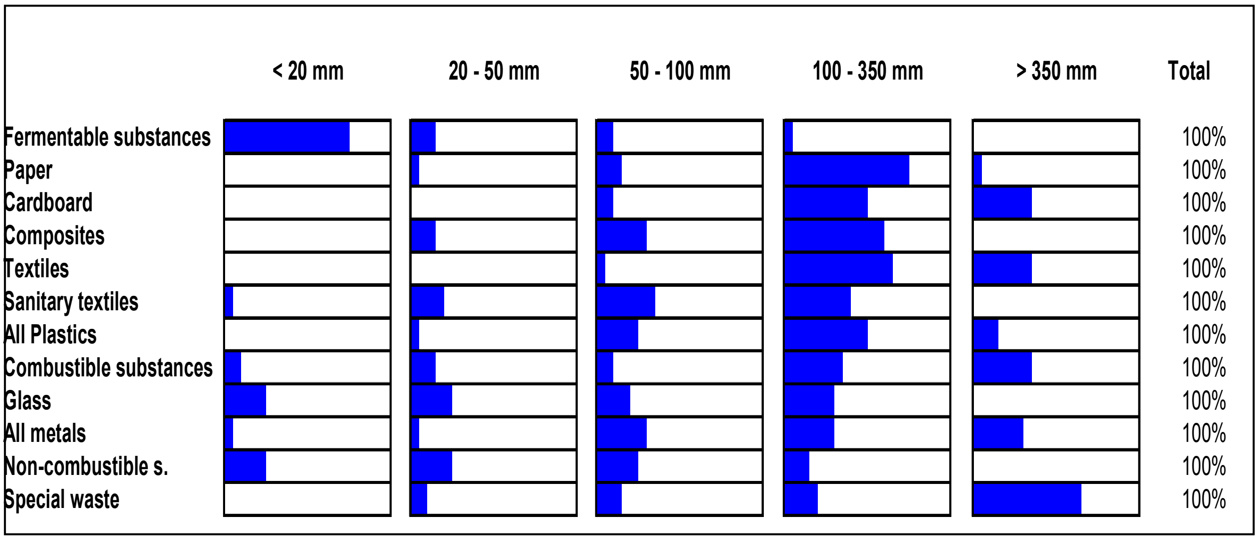

Figure 2: Granulometric distribution of the 12 categories of typical RHR

In summarised form, the bibliography shows that biodegradable organic matter basically comprises the following categories:

Table 3: Distribution of biodegradable organic matter in various categories

	Dry material % MB	**Total Organic Matter (TOM)**[10] % MS	**Biodegradable organic matter** % TOM
Fermentable substances	**35%**	**92%**	**98%**
Paper	**80%**	**80%**	**95%**
Cardboard	**85%**	**82%**	**98%**
Sanitary textiles	**39%**	**91%**	**90%**
Fine particles (<8 mm)	**55%**	**52%**	**96%**

In the case of biodegradable organic matter, these factors highlight a granulometric predominance, on the one hand in the 'coarse' fraction of 100 to 350 mm and, on the other hand, in terms of the fine particles.

Thus, the biodegradable organic matter in the RHR is primarily concentrated in the following 5 granulometric bands:

- category of fermentable substances: granulometric band <20 mm
- category of paper: granulometric band 100 – 350 mm
- category of cardboard: granulometric band >100 mm
- category of sanitary textiles: granulometric band 50 – 350 mm
- category of fine particles (<8 mm)

The relative distribution of the principal sources of biodegradable organic matter present in RHR can be shown in the form of a pie chart (below):

[10] TOM measured by loss in a flame at 550 °C

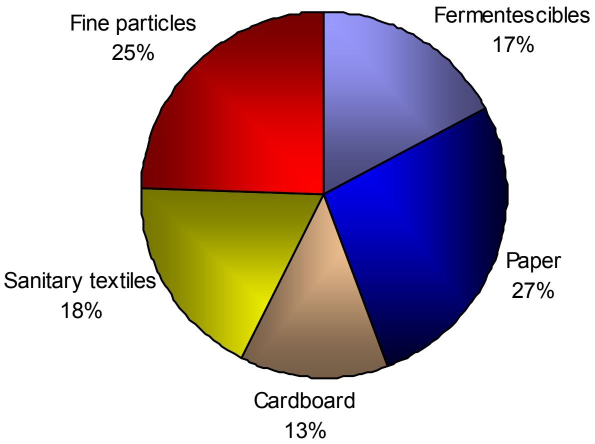

Figure 3 : Distribution of the biodegradable organic matter (as % of the gross) in a typical batch of RHR

From this it is possible to deduce a strategy for recovering this fraction of fermentable particles.

Based on the ratios shown above, the total biodegradable fractions contained in one tonne of gross RHR represents a potential of the order of 450 to 500 kg (gross) of total biodegradable fraction.

Reduced to the level of each occupant (on the basis of 300 kg gross/occupant/year of collected RHR), the biodegradable fractions represent a potential of the order of 140 kg untreated/occupant/year – excluding garden waste)., with paper and cardboard, which could represent up to 25 to 30% of the content of the residual rubbish.

4 Examples of MBT in France

4.1 Typology of operations

There is no typical preparation sequence. Each of the solutions consists of a combination of various types of equipment of varying complexity and diversified on the basis of the required degree of separation and, in turn, on the quality of the fertiliser substances produced in this way.

In this changing context, in which industrial performance is aimed at fulfilling the statutory requirements, some treatment organisations stand out from the rest.

Thus, the units which are experiencing growth in France are deploying:

- **upstream** of the biological process in its strict sense, biomechanical treatment using a rotating tube to prepare the substrate and to facilitate subsequent recovery of the biodegradable organic matter present in the larger granulometric particles, such as paper, cardboard and sanitary textiles
- at the heart of the process, aerobic or anaerobic biological treatment techniques
- a succession of negative and positive sorting techniques, by utilising the different properties of the constituent elements of the RHR

Thus, the operations involved include sorting the waste by its optical, mechanical, electrical, magnetic and electromagnetic properties, by its properties associated with its size and morphology and, finally, its surface properties.

4.2 Composting RHR

The characteristics of a current project involving an MBT plant to be set up in Western France, designed to produce 26,000 tonnes per annum from RHR, together with the production of an organic soil conditioner, are shown on the next page.

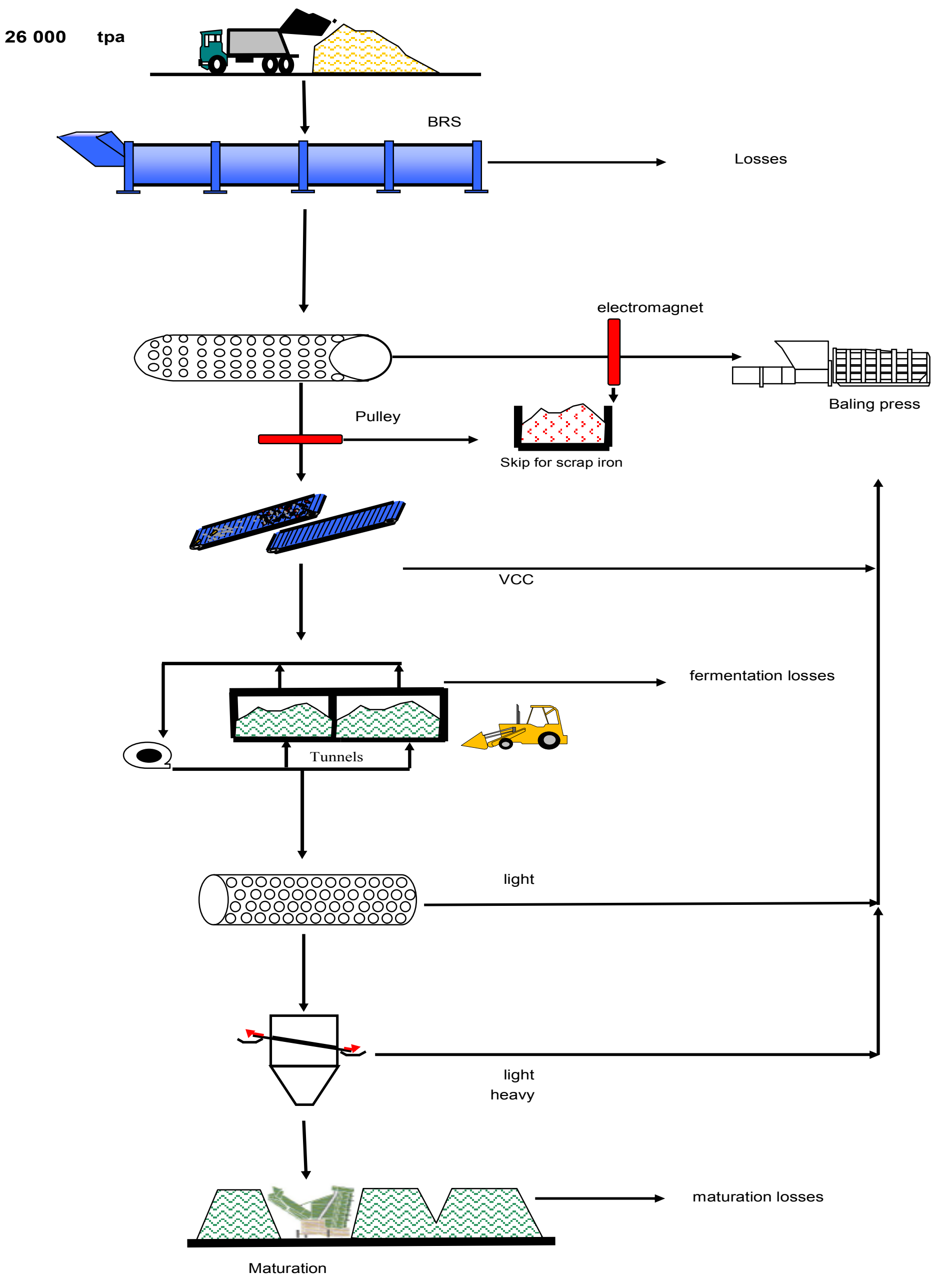

Figure 3: Schematic diagram of the MBT project (26,000 tonnes per annum)

The table below summarises the throughput of dry matter and biodegradable organic matter associated with the proposed main treatment levels:

Table 4: Throughput of dry matter and biodegradable organic matter

Workstations	**Roles**	**Throughput of dry matter** (kg DMS)	**Throughput of dry biodegradable organic matter** (kg DMS)
Receipt	Sort voluminous undesirable substances	1,000	500
Rotating tube	Granulometric reduction Homogenisation Biological decay Preparation of the substrate	900	410
Screen	Removal of plastics	600	320
DTS	Removal of heavy VCC	480	280
Composting	Biological decay Stabilisation Homogenisation, drying	400	210
Refining in the drum	Removal of small plastic items	270	170
Refining on the densimetric table	Removal of small plastic items Removal of small heavy items	250	160
Maturation	Stabilisation	210	140

The final rate of recovery (that is to say in terms of compost) of the biodegradable organic matter is estimated to be around 28%.

By incorporating the losses associated with biological treatment processes (biological treatment using the rotating tube for 4 days and biological treatment by composting for 4 weeks, followed by a 3-week period of maturation); the anticipated rate of recovery is of the order of 64%.

This is equivalent to a rate of recovery estimated at:

- 300 kg gross of biodegradable organic matter per tonne of treated RHR
- 85 kg gross of biodegradable organic matter per occupier and per annum (based on the production of 300 kg gross of RHR/occupant/year).

4.3 Digesting RHR

4.3.1 Dynamics of the methanogenesis process applied to residual household refuse

The French mechanical-biological treatment of residual household refuse, with methanogenesis of the organic fraction with a view to the production of a soil conditioner, is in a state of rapid growth:

- with 4 units in service (Amiens, Varennes Jarcy, Le Robert, Montpellier) and 2 units treating biowaste (Calais and Lille), with a total theoretical capacity of 560,000 tonnes per annum
- and with 4 allocated contracts (surveys in progress or construction in progress) in Marseilles, Romainville, Angers, Bourg-en-Bresse, Vannes and Forbach.

For the ADEME, responsible for monitoring the management of domestic waste, the rate of growth is of the order of 2 to 3 units per year, mainly involving Residual Household Refuse, with a few examples of biowaste collection having been identified (Forbach).

With regard to the technical approaches, two major choices are vying for approval:

- to introduce a 'clean' product into the digesters, which demands a fine sorting operation upstream and the use of a screen mesh of 0-10 mm for the separation process or
- to retain the maximum amount of organic matter at the input side of the digesters by carrying out a 'coarse' sorting operation, followed by a fine sorting operation on the digestate (using a hydraulic process for example)

In both cases, the majority of operators prepare the raw material using mixer tubes, with the aim of 'unsticking' the organic matter, that is to say rendering it 'easy' to hydrolyse and separate from the other constituents.

This is the objective driving the granulometric reduction operations.

4.3.2 Example of a methanogenesis plant treating residual household refuse (Bourg-en-Bresse, France)

This project (which is at the 'manufacturer's survey' stage: OWS – DRANCO + SORD-ISEP processes) is designed to treat an annual throughput of 90,000 tonnes of residual household refuse and 15,000 tonnes of green waste.

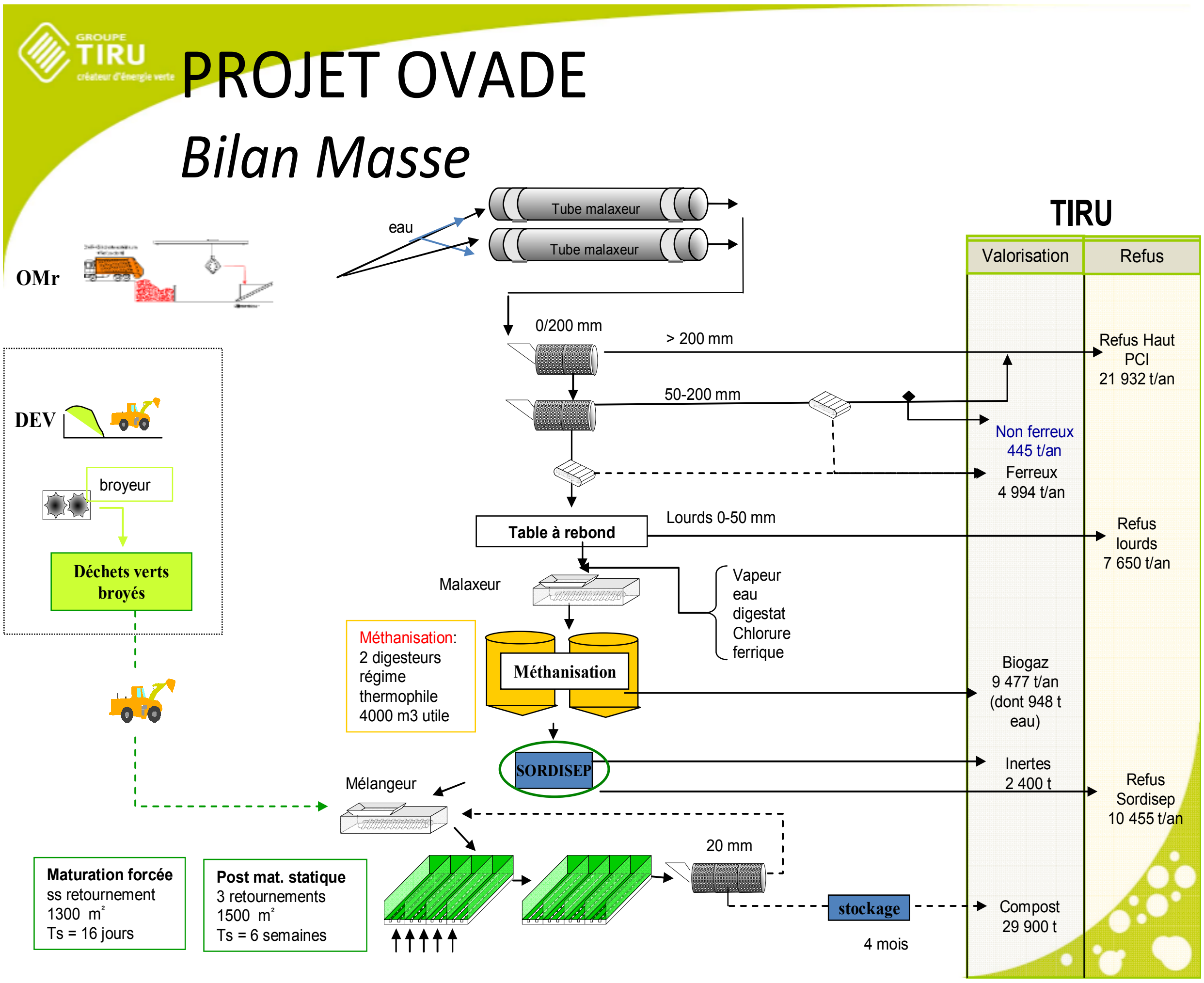

Figure 5: Schematic diagram of the MBT project at Bourg en Bresse

The contract has been placed on the basis of:

- digesters which are suitable for medium-sorted products (fraction 0 – 50 mm), without an agitation system and with an increased dry matter content (Dranco/OWS)
- a proven system for hydraulically sorting the inert substances (Sordisep/OWS)
- the absence of upstream crushing (mixing to facilitate separation of the constituents)
- and, finally, the production of compost which ensures total compliance with the ratio of inert substances stipulated by Standard NFU 44-051.

The principal ratios are as follows:

Biogas: 120 Nm3 / entry tonne, i.e. 250 kW/hr/tonne entering the digester

Diversion ratio: 54.6 %

Biogas: 10.5 %

Compost: 22.4 %

Clean inert substances: 2.7 %

Scrap iron: 5.5 %

Non-ferrous metals: 0.5 %

Evaporator: 13.0 %

Total : 54.6 %

In a subsequent stage, refuse with a high NCV - which constitutes 25.7% of the total mass - will be thermally recycled in a thermal treatment unit; this illustrates the complementary nature of the biological process with the energy recycling of refuse with a high NCV.

To summarise, the process involving methanogenesis of RHR demonstrates a high overall level of recovery of organic matter (optimisation of the production of biogas and compost) and methods to reduce the amount of refuse should be implemented.

4.3.3 Methanogenesis applied to household biowaste (Calais, 62)

Commissioned at the end of March 2007, during 2007 the unit treated a throughput of 6,350 tonnes, rising in 2008 to 12,000 tonnes.

The operation is characterised by a high proportion of green waste in the entry waste, with a ratio of 2/3 green waste after treatment.

Experience has shown that over and above a 30% proportion of grass cuttings at the entry to the digester, operation in thermophilic mode is no longer guaranteed and yet the volume of grass cuttings was as high as 80 to 90% of the green waste in spring and the start of the summer.

Therefore, during 2008, it became necessary to limit the volume of green waste to 50% in order to ensure that the digester operated satisfactorily.

In terms of operation, the ratio of production of biogas is 150 Nm^3/treated tonne. Furthermore, since the throughput of household biowaste was lower than the forecasts by the communities, the production of biogas was insufficiently high to power the generating set. The table

Table 8: Comparison factors between methanogenesis applied to RHR and to biowaste

	BIOWASTE	**RHR**
Treated organic waste	15 to 40 kg/ occupant/year	60 to 90 kg/ occupant/year
Production of biogas per tonne entering the digester	150 Nm^3/tonne	120 Nm^3/tonne
Assessed potential of biodegradable organic matter	≅ 30 %	≅ 70 %

5 Quality of the compost produced by MBT in France

The sanitary quality represents the major limiting factor in the production of organic soil conditioner derived from RHR.

For a typical batch of RHR, Figure 5 shows a breakdown of the 9 metals[11] stipulated by Standard NFU 44-051 for the principal categories and granulometric fractions of a typical batch of RHR:

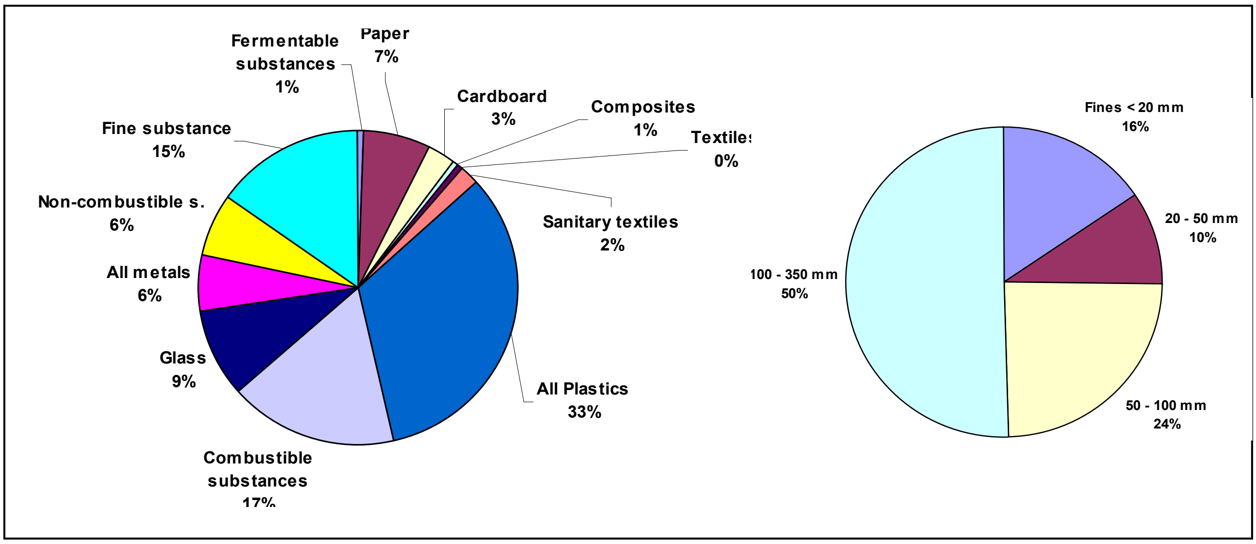

Figure 6: Breakdown of the 9 metals in RHR

[11] Total of the parameters As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn

The following tables summarise the limiting thresholds and throughputs stipulated by French and German regulations:

Table 9: Limiting thresholds for metals, as stipulated by French and German Standards

	Maximum contents, in mg/kg MS		
	D		Fr
	20 TWM	30 TWM	
As	-	-	18
Cd	1.5	1	3
Cr	100	70	120
Hg	1	0.7	2
Pb	150	100	180
Se			12
Ni	50	35	60
Cu	100	70	300
Zn	400	300	600
Fluoranthene	-	-	60
Benzo(b)fluoranthese	-	-	300
Benzo(a)pyrene	-	-	600

Table 10: Limiting throughputs of metals, as stipulated by French and German Standards

	Limiting throughputs g/ha over 1 year					
	D		F	D		F
	Maximum average throughputs*		Flux maximaux moyens**	Maximum throughputs at any given time*		Maximum throughputs at any given time**
	basis 20 T WM	basis 30 T WM		basis 20 T WM	basis 30 T WM	
As	-	-	90	-	-	270
Cd	10	10	15	30	30	45
Cr	667	700	600	2 000	2 100	1 800
Hg	7	7	10	20	21	30
Pb	1 000	1 000	900	3 000	3 000	2 700
Se	-	-	60	-	-	180
Ni	333	350	300	1 000	1 050	900
Cu	667	700	1 000	2 000	2 100	3 000
Zn	2 667	3 000	3 000	8 000	9 000	6 000

* Throughput calculated by comparison with the preceding table

** Stipulated throughputs

Current feedback shows that the content of metals and polyaromatic hydrocarbons does not represent a limiting factor regarding the compost produced by MBT.

Moreover, a number of studies have highlighted the significant presence of metals among the fine particles, particularly in heavily urbanised sectors. Large-scale recovery of the paper and cardboard contained in RHR in the MBT plants represents an important factor, enabling the compost to be enriched with organic compounds with a low metal content.

The most problematic point under consideration is the ratio of inert/undesirable substances. The overriding problem is achieving a satisfactory compromise between the production of a soil conditioner and the quality of the said soil condi-

tioner via the choice of a judiciously conceived refining process incorporated into the treatment sequence.

The final table (on the next page) highlights approaches which are totally incompatible with the one adopted by France and by Germany; these approaches do not employ the same parameters to characterise the inert substances in the compost and, in turn, their aesthetic quality.

Table 11: Threshold for inert substances specified by French and German regulations for urban compost

	Limiting values	
	Germany	France
Physical contaminants: glass, plastics, metal >2 mm	<0.5% MS	-
Stones >5 mm	<5% MS	-
Films + EPS >5 mm	-	<0.3% / MS
Other plastics >5 mm	-	<0.8 % / MS
Glass + metals >2 mm	-	<2.0 % / MS

6 Conclusion

The product of an organic soil conditioner from RHR ensures the optimum rate of recovery (and, in turn, recycling) of residual biodegradable organic matter.

However, this solution is only in its early stages in France.

Of the fifty or so MBT plants for RHR currently in operation, only 4 units are equipped with rehabilitated treatment lines suitable for the production of compost which complies with the new Standard NFU 44-051.

There is no question that the fifty or so projects in the course of development will confirm the long-term viability of the industry and, in particular, reconcile a high rate of recovery of biodegradable organic matter and satisfactory final quality for the types of compost produced, whose final destination is a return to the soil.

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