MSW FACILITIES OF COMBINED BIOLOGICAL TREATMENT: ANAEROBIC DIGESTION PLUS COMPOSTING

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1 INTRODUCTION

EU Landfill Directive (1999/31/EC) requires the gradual reduction of biodegradable municipal waste going to landfills. In this context, three mechanical-biological treatments (MBT) plants were designed and installed progressively in Barcelona Metropolitan Area (Catalonia, NE Spain) during 2000s. These facilities were intended to solve the problem of municipal wastes generated in this region (Table 1), especially to stabilise OM (organic matter) from MSW (municipal solid waste). Near to 600.000 tn/year of OF (organic fraction) is estimated to be produced in Barcelona Metropolitan Area but currently, a rough fourth part of it is separately collected (SC) to be biologically treated. However, it is worth noting that for both cases collection of plastic, glass and, paper and cardboard is provided. This means that most of the OF contained in MSW must be mechanically selected in the treatment plants. In general, the low recovered OF is explained by the low participation of the population in source sorted collection policies of OF, despite the application of the current legislation in Catalonia (Law 6/93 and Law 9/2008 on waste regulation), which obliges to sorted this fraction at source.

TABLE 1 **Characteristics of MSW generated by Barcelona Metropolitan Area (Catalonia, NE Spain) in 2008. (Source: ARC, 2010)**

Population (million)	**Total MSW generated (tn)**	**OF source sorted collected (tn)**	**MSW non-source sorted collected (tn)**	**Individual generation (kg/inh/day)**	**Potential OF (tn) (36%)1**
3.161.812	1.646.664	133.638	1.147.722	1,43	592.799

1 According to the Agència de Residus de Catalunya, 36% of MSW corresponds to organic fraction

TABLE 2 **Characteristics of the 3 facilities (F) in Barcelona Metropolitan Area. (Sources: EMA, 2010, * GC, 2006)**

	Surface (ha)	**Capacity (tn/year)**	**Input (tn/year)**	**OF treatment**	**Products**
F 1	6	300.000	SC 85.000 MSW 160.000	Anaerobic digestion and Composting (wet fermentation)	Recovered materials 11000 tn/year Biogas 3,58 milion m3 10300MWh/year Compost 25000 tn/year
F 2	8	240.000	SC 70.000 MSW 170.000	Anaerobic digestion and Composting (dry fermentation)	Recovered materials 23000 tn/year Biogas 12,6 milion m3 22000MWh/year Compost 38000 tn/year
F 3	1	260.000 (*)	MSW 160.000	Anaerobic digestion (wet fermentation)	Biogas 22GWh/year

Table 2 shows the main characteristics of the three facilities currently in operation in Barcelona Metropolitan Area, which treat organic fraction from two different types: source separated collection and mechanical sorting at facility. Facilities 1 and 2 combine anaerobic digestion and composting processes, whereas facility 3 only applies anaerobic digestion. In 2010, a fourth plant is under construction. The total capacity of the three installations are treating less than 40% of the total municipal waste generated in the area, but there are some other composting plants in the Metropolitan Area that treat part of the organic waste produced, while the rest is destined to other treatments. An important data to be considered in relation to their process is the amount of reject produced as a result of the mechanical selection and also of the final operations of digestate and compost production.

The general aim of this work was to assess the operation of these 3 facilities. In particular, we studied (1) the quality of the OF, based on % of non fermentable materials (or impurities), from source sorted collection (SC) and also from mechanical sorting (MS) at facility, (2) characteristics of organic fraction and middle products of biological processes and (3) quality of obtained compost.

2 MATERIALS AND METHODS

2.1 Sampling methodology

Like this facilities are very complex, a good knowledge of the whole process and a good approach on the sampling points is crucial to provide an easy development of sampling and to ensure that a representative samples are taken. So, first step was to determine the material flow through the facility. The contact with managers and their knowledge about the biological process were essential to achieve this purpose.

Samples of the whole process were taken from the three facilities. Figure 1 shows a simplified diagram of the processes conducted in a generic facility of combined biological treatment, and sampling points labelled with grey dots. Two main lines can be observed depending on the selection treatment: (1) source sorted municipal solid waste organic fraction (OF-SC line) and (2) non source sorted municipal solid waste organic fraction (OF-MS line). In both lines, anaerobic digestion and composting treatments were carried out, so that it is obtained four different composts: (a) compost from composting organic fraction separately collected (OFSC-C), (b) compost from anaerobic digestion of organic fraction separately collected (OFSC.AD-C), (c) compost from composting organic fraction mechanical sorted in the same plant (OFMS-C) and (d) compost from anaerobic digestion of organic fraction mechanical sorted (OFMS.AD-C).

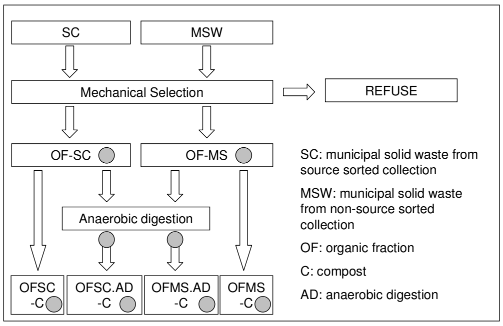

FIGURE1 **Simplified diagram of facilities and sampling points.**

2.2 Sampling methodology

(a) Quantification of the % of impurities and % of OF in solid samples was conducted on wet sample, sorting them by hand and weighing them to calculate their proportion in relation to the total mass considered.

(b)Solid and semi-solid samples: EC (dS m-1) and pH were measured from water extract (1:5 w/v) on wet samples, using a pH electrode and an electrical conductivity probe, respectively. Water extractable ammonium (NH4+-N, g kg-1 dry weight basis) was measured in the same extract using a specific ion electrode. The characterisation of the organic fraction was carried out on the dry (105ºC to a constant weight) and milled samples. Results are expressed in g kg-1 dry weight basis. Total organic matter (TOM) was determined by weight loss on ignition heating for 4 h in a muffle furnace at 560°C. Mineral matter (%MM) is %MM=100-%TOM. Organic nitrogen (% org-N) was determined with a specific ion electrode after Kjeldahl digestion. C/N was calculated by dividing OM/2 (Zucconi and de Bertoldi, 1987; Saña et al., 1989). Parameters relating to organic matter and nitrogen stabilisation (ROM, SD, nh-N and rN) were conducted according to Klason modified method (López, 2010) and Saña et al. (1989): ROM and nh-N were determined as TOM and org-N in the dried residue obtained after two successive sulphuric acid hydrolyses (one in a cool for 3 hours with 72% H2SO4 followed by a second boiling hydrolysis under reflux for 5 hours in H2SO4 0,7N). Stability degree (SD) expresses the percentage of ROM with respect to TOM content and resistant nitrogen (rN) expresses the percentage of nH-N relative to org-N content. Heavy metals (expressed as g kg-1 dry weight basis) were determined by atomic absorption spectrometry after dissolution of ashes (ignition at 470ºC) in 3N HNO3.

3 RESULTS AND DISCUSSION

3.1 Quality of the organic fraction

Impurities content in organic fraction in biological treatment plants can be highly variable depending on season and local areas, but above all, on the efficiency of the source sorted collection system (ARC, 2010). The results in table 3 reflect the inadequate participation of population in source sorted organic fraction collection since the percentage of impurities is high, especially in these facilities. It should be notice that these percentages are usually higher than those ones showed by the average presented by the organic fractions treated in the rest of the Catalan SC composting facilities.

TABLE 2 **Percentage of impurities (%±SE) in municipal waste collected in F 1 and F 2 and comparison with the total of Catalan composting plants (ARC, 2010)**

	F 1 (SC+MSW)	F 2 (SC+MSW)	Catalan composting SC plants
2006	30±2,92	18±1,07	15±0,37
2007	17±0,90	14±0,93	10±2,08
2008	22±1,14	10±1,00	11±0,26

The quantification of the % of impurities and OF done from a total of 200kg of fresh sample (unloaded from lorries randomly selected in F 1), showed a lower proportion of OF in the SC (58,6%) coming from the streets than in the SC coming form markets (91,2%). The remaining percentage corresponded to refuse, mainly plastic from packaging.

On other hand, mechanical selection systems in each facility are different, which can affect the selection of organic fraction before starting the biological treatment. The characterization of the refuse obtained after mechanical selection (figure 1) in both lines OF-SC and OF-MS, pointed out that the refuse from OF-SC line contained a 25,4% of organic matter yet, that has not been recovered through mechanical selection and which final destination is landfiling or incineration. In OF-MS line, only a 7,4% of OF was detected in the refuse but this figure could be associated with a lower OM content of MSW (in relation to SC) than with a higher efficiency of MSW selection.

These results show that the mechanical selection, besides needing larger surface and investment for the selection devices, it seems not be as effective as source sorted collection made by citizens. In fact, effectiveness in source collection can be noticed in a small plant (in the municipality of Malla), involved in door by door collection of organic waste, which results for 2009 showed an average of impurities of 1±0,07% (ARC, 2010).

3.2 OF-SC, OF-MS and digestate characterization

Organic fraction after mechanical selection (OF-SC and OF-MS) showed different characteristics from those observed for SC in our previous work (López et al., 2010) where the organic fraction was analyzed at arrival in bags to the OF SC composting plants. The main differences were lower contents in moisture and organic matter, and higher heavy metal contents (Table 4). On the other hand, it should be noticed that similar heavy metal levels were observed between OF-SC and OF-MS in F1 and F2, and clearly higher than those observed in SC.

Digestates from these plants (Table 5) result in a higher pH respect the observed in organic fraction (Table 4). For all digestate samples, a high content in ammonium was detected. Moisture content is according to the technology applied, resulting in lower content in F 2, whose anaerobic digestion is conducted on dry (Table 2). Digestates TOM contents are lower in F 2 and 3 than in F 1, suggesting a slighter degradation during AD in F 1. Moreover, organic nitrogen content results higher in F 3. Heavy metal content seems to be higher in F 3 than in F 1 and 2.

3.2.1 Compost quality

In relation to compost quality from materials coming from anaerobic digestion, it must be considered that F 3 only produces digestate but not compost. Table 6 shows the differences in composts between F 1 and 2, and they are compared with compost from not digested source sorted collection of organic fraction (OF-C) obtained from different facilities and with compost from not digested MSW (MS-C) of other plants.

TABLE 3 **Characterization of OF after mechanical selection compared to means values of OF-SC in Catalan composting plants**

	F 1 (2006)		F 2 (2007)		F 3 (2008)	Catalan SC plants
	OF-SC	OF-MS	OF-SC	OF-MS	OF-MS	SC (López et al., 2010)
pH	5,31	5,76	5,73	4,97	6,15	5,26
EC (mS cm-1)	4,16	5,32	4,37	6,28	3,78	3,43
Moisture (%)	59,18	50,80	54,64	65,56	44,42	70,84
N-NH+4 sol. (mg kg-1 sms)	562	514	689	1307	460	808
TOM (% sms)	78,60	68,74	74,52	79,36	77,37	85,15
Norg (% sms)	2,22	2,49	1,43	3,09	1,84	2,65
C/N	18	14	26	13	21	17
Zn (mg kg-1 sms)	144	126	75	68	40	34
Cu (mg kg-1 sms)	30	49	42	23	33	15
Ni (mg kg-1 sms)	5	7	5	3	4	2
Cr (mg kg-1 sms)	12	26	8	4	9	2
Pb (mg kg-1 sms)	46	54	14	7	51	4
Cd (mg kg-1 sms)	0,13	0,37	0,3	0,3	0,11	0,3

TABLE 4 **Characterization of DIGESTATES**

	F 1 (2006)		F 2 (2007)		F 3 (2008)
	OF-SC	OF-MS	OF-SC	OF-MS	OF-MS
pH	8,05	8,15	8,58	8,48	8,92
EC (mS cm-1)	4,18	4,55	5,30	5,54	3,50
H (%)	69,59	71,02	50,57	49,26	65,82
N-NH+4 sol. (mg kg-1 sms)	5020	6603	4651	4909	4090
TOM (% sms)	67,69	61,98	54,22	57,37	55,24
Norg (% sms)	1,58	2,01	1,27	1,18	3,71
C/N	21	15	21,46	24,35	7
Zn (mg kg-1 sms)	234	139	104	148	524
Cu (mg kg-1 sms)	95	90	78	143	167
Ni (mg kg-1 sms)	16	14	5	10	37
Cr (mg kg-1 sms)	17	19	9	14	30
Pb (mg kg-1 sms)	38	42	26	34	87
Cd (mg kg-1 sms)	0,54	0,39	0,64	0,79	3,59

Slight differences between the composts from these plants were observed and no clear relation can be established in relation to the origin of the raw material (source collection or not) or to treatment applied in plant (anaerobic digestion or not). This apparent homogeneity could be attributed to the fact that both lines are not properly differentiate along the process. Compost from these plants was similar to those obtained in MS facilities. In relation to OF-C present a higher N-NH4+ and heavy metal content, and lower nitrogen (orgN and NnH) and stability. Organic matter results different from products, and in F 2 it can be noticed that compost without previous digestion of OF shows higher values of TOM. Heavy metal content does not seem to differ between these plants samples and, in relation to Spanish regulation (RD824/2005) the use of these composts is restricted, and attending to the maximum limit established should be landfilled.

4 CONCLUSIONS

- Mechanical separation systems used to obtain a suitable initial material to perform anaerobic digestion, despite having been optimized, seems not to have enough efficacy considering their high economical cost, large space occupation and high content of rejects with a high organic matter content.
- Lines for SC and for MS seem to be not sufficiently differentiated. For this reason, neither digestate nor the final compost showed the expected differences according to the type of starting material, including heavy metal content.

– The fact that the obtained products are very low in quality, especially in relation to heavy metal content indicates that the compost obtained in this type of facilities should be landfilled rather than be used as organic amendments.

TABLE 5 **Characterization of COMPOSTS from F 1 and F 2 and comparison to compost from source collection (OF-C) and from non source collection (MS-C).**

	F 1			F 2				Other facilities	
	OFSC.AD -C	OFMS.AD -C	OFSC -C	OFSC.AD -C	OFMS.AD -C	OFSC -C	OFMS -C	OFSC -C	OFMS -C
pH	7,76	7,98	8,08	8,32	8,69	7,79	7,63	7,8	7,5
CE (mS cm-1)	7,48	8,63	9,35	6,15	8,00	8,07	7,76	7,2	8,3
H (%)	30,91	28,76	25,86	34,89	33,26	35,09	34,25	27,1	27,6
N-NH+4 sol. (mg kg-1 sms)	2236	2459	2754	1600	2863	3488	2838	1103	1880
TOM (% sms)	41,83	59,84	47,98	49,65	54,93	63,72	62,77	53,50	48,9
Norg (% sms)	1,28	2,07	1,68	1,48	1,67	1,72	1,70	2,2	1,5
C/N	16,38	14	14	17	16	19	19	13	16
%ROM	17,70	22,56	19,92	22,35	22,31	25,36	25,07	25,12	18,69
%SD	42,31	37,71	41,51	45,12	40,77	39,80	39,91	46,20	39,11
%NnH	0,62	0,90	0,73	0,69	0,61	0,71	0,71	1,16	0,64
%Nr	48,32	43,48	43,60	46,83	36,87	41,43	41,68	49,85	41,17
Zn (mg kg-1 sms)	445	401	405	277	408	299	411	205	544
Cu (mg kg-1 sms)	465	304	267	298	216	154	191	99	239
Ni (mg kg-1 sms)	34	38	34	24	31	21	27	58	112
Cr (mg kg-1 sms)	33	42	80	22	21	16	25	41	98
Pb (mg kg-1 sms)	139	107	102	51	76	59	73	58	172
Cd (mg kg-1 sms)	0,60	0,52	0,53	0,85	0,81	0,55	1,10	0,37	0,97

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