Effect of a further maturation phase on the leaching behaviour of MBT waste

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Abstract:

This work aimed at evaluating the environmental behaviour of treated Municipal Solid Wastes (MSW) produced in the city of Rome from a Mechanical-Biological Treatment (MBT) plant, and at assessing how a further maturation stage, typically scheduled only for the source segregated organic fraction of MSW after their aerobic bio-degradation in composting plants, can influence the main chemical properties of these materials. To this end, preliminary characterization and batch leaching tests were performed on a MBT waste as received and on a sample that underwent a 90 days-maturation phase. The obtained results revealed that the implementation of the further maturation stage could influence significantly the organic matter content as well as the total metals content in the solid matrix and the leaching behaviour of the material. Furthermore, for the investigated waste, it was observed an evident variation between the leaching values of the dissolved organic carbon (DOC) over time. These results evidenced that it is still possible for MBT wastes to reach an improvement of their environmental characteristics, by implementing a further maturation stage at natural aeration condition.

Key words: Municipal Solid Wastes (MSW), Mechanical-Biological Treatment (MBT), Maturation, Metal Content, Leaching Behaviour.

1. INTRODUCTION

According to the EUROSTAT data, the amount of Municipal Solid Waste (MSW) generated in the EU 28 was around 242,300 Mg in the 2015. Excluding residues from construction and demolition, soils and other minerals, this fraction represented around 34.7% of the total waste production (242,300 on 698,980 Mg), suggesting that MSW can be considered a relevant contribute. Specifically, as far as the management of MSW in the 28 Member States is concerned, in 2015 29.4% of these wastes was recycled, 16.8% composted or anaerobically digested, 27.5% incinerated and 26.3% landfilled. However, as established by the European Landfill Directive 1999/31/EC, the disposal has to be considered the last option in the waste management and the amount of landfilled waste has to be limited. To this aim, many countries adopted different controlled biodegradation processes to treat the Organic Fraction of the MSW (OFMSW) such as the source separate collection of the OFMSW to produce compost, the Mechanical–Biological Treatment (MBT) of residual MSW to produce bio-stabilised waste, as well as residual MSW combustion to produce energy. Compost is generally reused for its physical and chemical properties as a fertiliser or a soil conditioner. However, when the composting treatment is not viable, metals and other not-degradable fractions (as plastics and glasses) that are present in the residual municipal solid waste need to be mechanically removed before the biological treatment and can be recovered and reused instead of raw materials.

Even though the "end of waste criteria" for the bio-waste are not clearly issued at European level, many of the Member States provided their own regulations on the treated bio-waste characteristics suitable for agronomic recovery. It is important to emphasise that generally, in these regulations, the characteristics for waste reuse are expressed only in terms of the total composition (e.g. heavy metals content), whereas no restrictions on the leaching behaviour are prescribed. However, it has to be pointed out that leaching could represent a potential release of organic and inorganic compounds in the environment [19], especially in groundwater, and the leachate composition may provide useful information about the long-term environmental impacts.

To date, many studies investigated the total composition and the leaching behaviour of composts, confirming that bio-stabilisation of the organic fraction of MSW is enough to obtain materials suitable as natural fertilizers [2, 13]. Differently, the bio-stabilised organic waste from mechanical–biological treatment of residual mixed MSW is mainly landfilled or, in a few cases, employed for landfill covering due to the higher content of non-compostable materials and heavy metals [1, 3, 5]. Furthermore, MBT wastes generally show lower biological stability if compared to a compost, due to the different treatment time. Namely, a controlled one month-bio-stabilisation stage is required for both compost and MBT waste, but only for compost a secondary maturation stage to improve the material quality is planned. However, the lower stability could lead to a higher release of organic carbon and metals bounded to organic fraction in water. This suggests that environmental properties of the MBT waste can be potentially improved by extending the bio-stabilisation period.

This study was aimed at assessing and comparing the physico-chemical characteristics and the leaching behaviour of an MBT waste produced from an aerobic process before and after a further 90 days-stabilisation step.

2. MATERIALS AND METHODS

2.1 Materials

The MBT waste was collected in one MBT plant located in Rome. In this plant, after a primary sieving to remove the dry light materials with dimensions higher than 90 mm, the wastes underwent metal removal by belt-type electromagnetic separators and a 4-weeks aerobic biodegradation at forced aeration conditions. The biostabilized output is then mechanically sieved at 30 mm in order to remove the coarser fraction, mainly composed of plastics and inert materials, from the finer one, so to obtain the organic fraction of the wastes.

2.2 Maturation Tests

Namely, a 300 kg-sample of MBT waste was collected at the end of its treatment and it was stored indoor for about 90 days. During this period the sample was manually overturned and humidified, in order to simulate the typical maturation phase adopted in composting processes. Water content was kept constant at around 75% of the water holding capacity (WHC) to ensure optimal conditions for bacteria activities. A preliminary characterization was carried out at the beginning of this stage, in order to investigate the biological stability degree (i.e. determination of the Dynamic Respiration Index), the organic matter content, in terms of volatile solids (VS) and total organic carbon (TOC), and the total metals content of the solid matrix. Then, the leaching behaviour was investigated by performing batch leaching tests, in order to evaluate and compare the extent of the metals release, which is mainly employed for compliance purposes, with the dissolved organic carbon (DOC). All the analysis have been repeated after 90 days, in order to evaluate the effects of the further maturation phase on the compound release.

The DRI index was measured by means of an adiabatic respirometer on 10-12 kg of material according to the procedure reported in the Italian Standard UNI/TS 11184 (2016) [17]. The organic matter content was assessed by measuring the Volatile Solids (VS) and the Total Organic Carbon (TOC). According to

UNI/TS 11184 (2006) [17], VS content was determined on a 10g sample of material grinded to size lower than 0.5 mm and pre-dried at 105 °C for 4 h, measuring the loss-on-ignition after 6 h at 550 °C. TOC content was analysed by means of Shimadzu SSM-5000A instrument on approximately 0.1 g of sample grinded to size lower than 0.2 mm, in accordance with the UNI EN 13137, (2002) [15]. Total heavy metals content in the solid matrix was analysed by performing an acid digestion in an ultrasonic bath using a solution of aqua regia (a mixture of HNO_3 and HCl, in ratio 1:3) at 80 °C for 60 minutes. After cooling, the obtained solution was analysed by ICP-OES-Varian 710-ES. Batch Leaching Tests (BLT) were performed according to the test method UNI EN 12457-2 (2004) [16], to evaluate the leaching behaviour of the tested materials and the changing in leachability with time. Around 10 g of the MBT waste were put in contact with deionized water at a liquid to solid ratio (L/S) of 10 l/kgTS for 24 hours, under constant agitation. The obtained solution was filtered at 0.45 μm and the concentration of heavy metal and DOC in the eluate were analysed by ICP-OES and Shimadzu TOC-V CPH/CPN analyser respectively. For the elemental composition of the sample before and after the maturation stage, a CHNS-O analyser (FLASH 2000 – Organic Elemental Analyzer) was used. All the analyses were carried out in triplicates, except for the biological stability degree.

3. Results and discussion

The main results obtained for the MBT waste as received and after 90 days of maturation are reported in Table 1. As can be seen, a further maturation stage proved to be effective in increasing the removal of the biodegradable fraction contained in this material. Indeed, after 4 weeks of the occurred bio-stabilization phase in the MBT plant, DRI was 1503 O_2/h*kg VS, hence higher than the threshold value of 1000 mg O_2/h*kg VS suggested for bio-stabilized organic wastes [6]. At the end of the further 90 days-maturation stage, instead, the DRI proved to be significantly decreased (i.e. equal to 369 mg O_2/h*kg VS).

The pH of the as received MBT waste was around 8, hence in agreement with the range of values expect for a bio-stabilised waste [9, 12], and proved to remain almost constant for the 90 days of maturation. In the as received MBT waste, the humidity was 21.9% of the total dry weight hence too low to respect what is indicated in UNI/TS 11184 (2016) [17] that describes the conditions required for allowing an effective microorganism's bio-degradation activity during the respirometric analysis. Hence, during the 90 days-maturation phase water was added to the sample in order to increase the humidity to values close to 75% of the water holding capacity (WHC). At the end of the maturation phase the humidity and WHC was equal to 32.5% and 53.7% respectively (see Table 1).

Table 1. Main chemical properties of the MBT waste material at the beginning and after 90 days of maturation (mean ± standard deviation)

		0 days	90 days
DRI	mg O_2 / h*Kg VS	1503	369
pH	-	8.01 ± 0.04	8.13 ± 0.03
Humidity	%	21.89 ± 0.17	32.45 ± 1.44
WHC	%	58.20	53.67
VS	TS %	59.10 ± 3.14	39.43 ± 0.79
TC	TS %	30.78 ± 4.50	21.62 ± 2.02
IC	TS %	1.25 ± 0.09	2.02 ± 0.24
TOC	TS %	29.53 ± 4.51	19.60 ± 2.31
DOC	mg/l	3330 ± 158	599 ± 36

During the maturation phase, the volatile solids decreased from around 59.1% of the total dry weight to 39.4%. The organic carbon (TOC), wich represented around 29.5% of the weight of the Total Solids (TS), followed a similar trend and was equal to 18.5 at the end of the study (Figure 1a). On the other hand, the inorganic carbon (IC) significantly increased passing from 1.25% to 1.92% (Figure 1b).

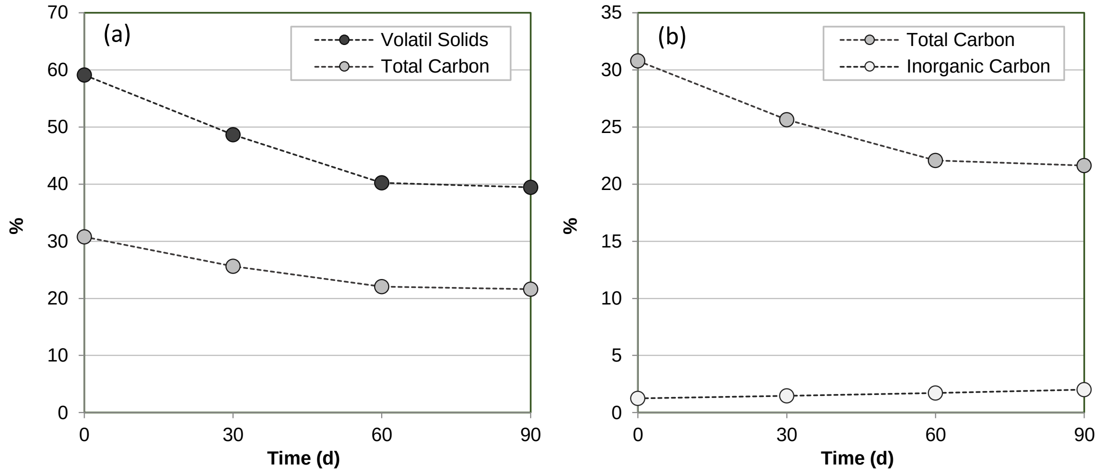

Figure 1. Volatile Solids and Total Carbon (organic and inorganic) trend during the maturation stage, based on the percentage by dry weight

As far as the DOC is concerned, it represented 11.28% of the total organic carbon that was originally in the sample (around 33.3 g/kg compared to 295 g/kg of TOC). After 90 days, the DOC was around 6 g/kg, representing only 3% of the final TOC (equal to 196 g/kg) showing a lower propensity of the organic carbon to be issued in the leachate. It has to pointing out that the initial concentration strongly depends on the composition of treated MSW waste, and its rate of decrease during the maturation stage might be influenced by the process that is applied and by the source material, as with compost as result of composting processes [21]. The DOC value measured in this study for the MSW waste after a 3 months maturation stage was lower than the threshold of 10 g/kg suggested for compost by Hue and Liu [8], even if it is important to highlight that, in their work, most of the examined composts had DOC concentrations lower than 4 g/kg.

Table 2 shows the results of the elemental composition analysis performed on the samples collected each 30 days during the maturation phase. In agreement with the results obtained by TOC-meter for the total carbon content (TC), the C content showed a decrease from 29.4% to 24% and the H content passed from 4.5% to 3.46%. The C/N ratio was also calculated as an additional index for assessing the effectiveness of the maturation stage, because it is occasionally proposed as a compost quality indicator [7, 10]. Based on the C/N value, considering that composts are usually considered mature with a C/N ratio of 10–15, the MBT waste considered in this study proved to reach a proper maturation level.

Table 2. Results of the elemental analysis, based on the percentage by dry weight (mean ± standard deviation) and the corrispective C/N ratio values

Days	C [%]	H [%]	N [%]	S [%]	C/N
0	29,43	4,46	1,95	0,75	15,11
30	25,01	3,52	1,73	0,63	14,48
60	22,11	2,89	1,62	0,29	13,61
90	23,98	3,38	2,56	0,66	9,36

Figure 2 shows the total heavy metal content of the MBT waste before and after the maturation phase. The initial values resulted comparable with the ones observed in other studies for wastes produced from the biological treatment of the mechanically separated biodegradable organic fraction [1, 14, 20]. After 90 days of maturation an increase in the heavy metal content was observed due to the weight loss occurred in the biological treatment for the organic matter decomposition exerted by microbiological activity. The amount of metals released in water from the MBT waste was assessed based on the results of the batch leaching tests (see Figure 3). Namely, the percentage of release of the heavy metals was calculated comparing the concentrations of these elements in the eluate with their total content in the MBT waste. As can be seen, the metal release observed for the as received MBT waste was generally lower than 10% for most of the considered metals, except for Mo and Ni, and, as shown in Table 3, it always fulfils threshold criteria for the landfill (not hazardous waste) eligibility set by the Italian legislation (D.M. 281/2010) (see Table 3).

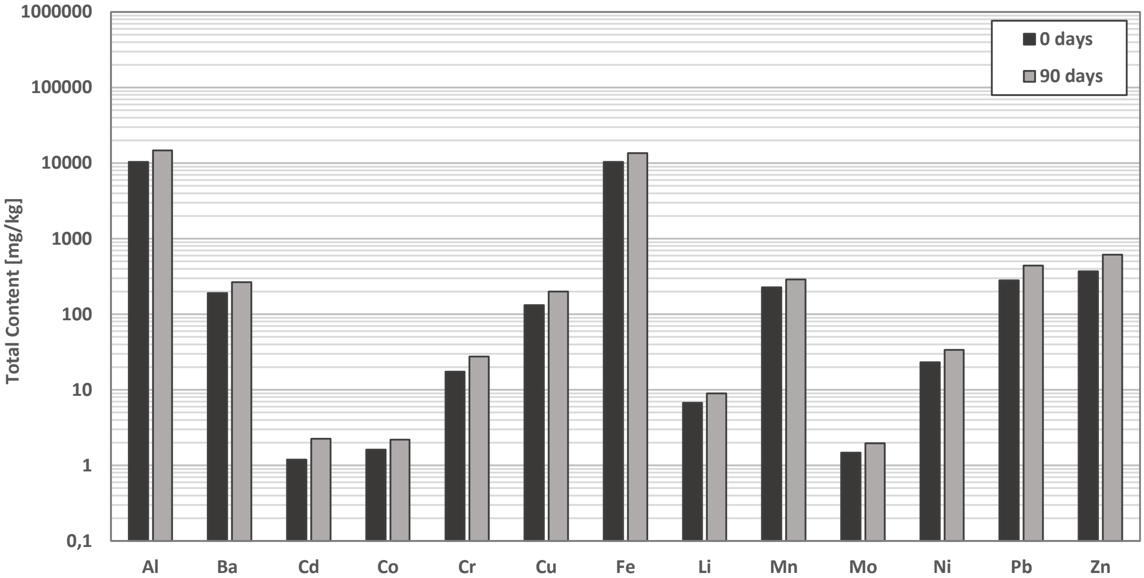

Figure 2. Comparison of the total heavy metal content of the waste after 0 and 90 days of maturation (the values are referred to the percentage by dry weight)

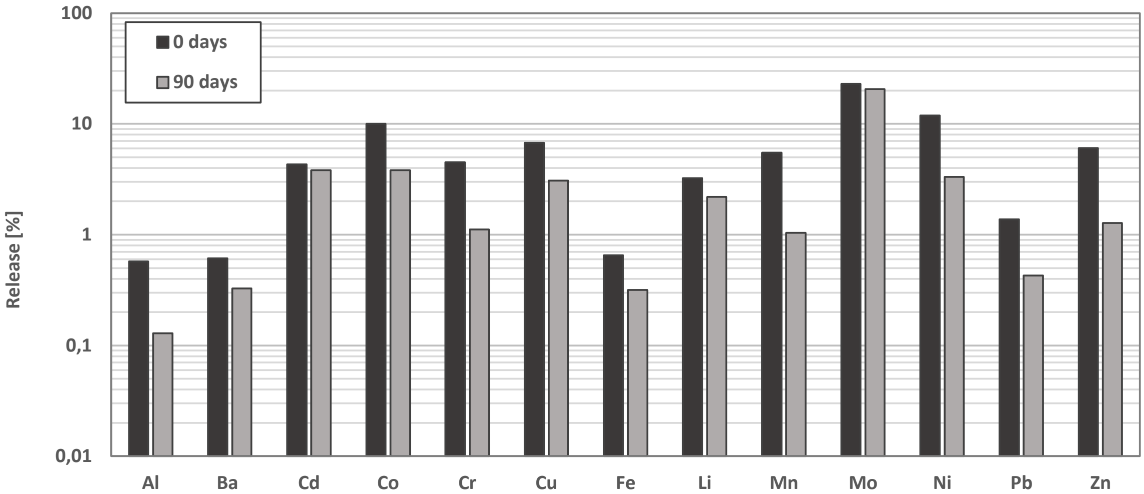

Figure 3. Comparison of heavy metal percentage release between 0 days 90 days

After the maturation stage, most of the elements (i.e. Al, Co, Cr, Cu, Mn, Ni and Zn) showed a lower release that might be related to the lower organic carbon dissolved in solution and the mineralization processes [3, 5, 20]. The DOC, in fact, is one of the key factor in controlling the metal release (especially of Cu, Cr, Ni and Zn), due to its ability to form stable soluble organic complexes with metal ions [11, 19]. The release of other elements, such as Cd or Mo, remained almost constant after the maturation phase.

Table 3. Results of the batch-leaching test of MBT waste compared with the Italian baseline regulation (* Italian Ministerial Decree No 281 (2010) about the landfill eligibility criteria (not hazardous waste))

	BLT 0 days [mg/l]	**BLT 90 days [mg/l]**	*** D.M. 281/2010 [mg/l]**
Ba	0,12	0,09	10
Cd	0,01	0,01	0,1
Cr	0,08	0,03	1
Cu	0,89	0,61	5
Mo	0,03	0,04	1
Ni	0,28	0,11	1
Pb	0,39	0,19	1

4. Conclusions

In this study the effects of a further 90 days-maturation step on the main chemical properties and on the environmental behaviour of a bio-stabilised organic waste from Mechanical-Biological Treatment (MBT) of residual mixed MSW were investigated.
After 90 days of maturation, it was possible to observe a general enhancing of the biological stability of the sample. The Dynamic Respiration Index (DRI) proved to be significantly affected by the applied maturation phase suggesting that the enlargement of the bio-stabilisation period could lead to a reduction of the biodegradable fraction contained in this material, as remarked by the data obtained for volatile solids and total carbon content. As far as the DOC is concerned, the release of organic carbon in the leachate decreased during the maturation stage and, after 3 months, it was quite similar to typical values of a good bio-stabilised compost. The total heavy metals content resulted comparable with the ones observed in other studies on wastes produced from the biological treatment of the mechanically separated biodegradable organic fraction [11] showing higher metals concentration with the maturation, due to the weight loss occurred in the biological treatment for the organic matter decomposition exerted by microbiological activity. The metal release observed for as received MBT waste generally decreased with biological stability improvement, probably related to the lower organic carbon dissolved in solution and the mineralization processes [11].

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