Quality evaluation of mechanically-biologically treated MSW subjected to longer duration of biological treatment

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Abstract

In the present work, the influence on the quality of mechanically-biologically treated municipal solid waste subjected to longer duration of the aerobic biological process was evaluated. For this purpose, biological and physical-chemical characterisation of the material periodically sampled during the aerobic biodegradation lasting 7 weeks (instead of 4 weeks) was carried out. Specifically, investigations on biological stability degree, heavy metals total content and contaminant release in water phase (leaching behaviour) were performed. Results showed that, after 4 weeks of biological treatment, the waste was still quite reactive. By extending the process duration to 7 weeks, a good biological stability degree was reached. Furthermore metal total contents in the stabilised biowaste sampled at the 7th week of biodegradation fulfilled the limits set for environmental recoveries (such as landfill cover). Lastly, release of contaminants showed to increase during the biological process for some metals likely because of the high affinity with dissolved organic carbon. However further investigations on metals leaching need to be performed in order to better understand leaching behaviour and the controlling factors. Such evaluations could be useful in the development of a quality standard, currently lacking, which could identify the most suitable recovery or disposal in relation to the specific characteristics of the stabilised biowaste.

Introduction

In the last two decades mechanical-biological treatment (MBT) of residual municipal solid waste (i.e. the remaining MSW after separate collection) was developed in order to minimise the environmental impacts and reduce the risk to human health associated to the disposal in landfill, as required by the European Landfill Directive 1999/31/EC (European Commission, 1999). The goal of MBT broadened over years with the further purpose to utilise significant percentages of the outputs for material and/or energy recovery (Farrell & Jones, 2009; Velis et al., 2010). One of the output of MBT is the stabilised biodegradable waste (SBW) produced from the biological treatment, generally consisting of aerobic biodegradation, of the biodegradable organic fraction mechanically separated from the input MSW. As indicated in the document drafted by the European Commission "Biological treatment of biowaste - 2nd draft" (European Commission, 2001), the MBT of biowaste shall have the purpose of stabilising and reducing the volume of the biodegradable waste in order to ensure that it can either be used for ecological improvement or has reduced negative environmental impacts when landfilled. Moreover the EC document specifies that Member States may authorise the use of stabilised biowaste, fulfilling the requirements indicated in the document, as a component in artificial soils or in those land applications that are not destined to food and fodder crop production (such as final landfill cover, landscape restoration in old and disused quarries and mines, anti-noise barriers, road construction, etc.). Such statement came from the evidence that the content of heavy metals in SBW is generally higher than that in compost produced from source segregated waste (Amlinger et al., 2004; Di Lonardo et al., 2012a; Smith, 2009). Nowadays, in Italy, stabilised biodegradable waste is mainly disposed of in landfill. Data provided by the Institute for the Environmental Protection and Research in "Municipal Solid Waste Report – Edition

2013” (Laraia, 2013), show that 84 % of the total quantity of stabilised biowaste produced in 2011 (roughly 20 % of MSW feeding MBT plants) was sent to landfilling. Hence, the present study aimed to assess the quality of SBW coming from one of the four MBT plants operating in Rome for a potential sustainable recovery in alternative to landfilling. In a previous study (Di Lonardo et al., 2012b), stabilised biowaste as currently treated in the MBT plant of Rome, showed to not have a suitable quality for waste recovery. Therefore the influence on SBW characteristics of longer duration of the aerobic biological process from 4 weeks (which is the duration in normal operating conditions of the plant) to 7 weeks was evaluated. For this purpose, biological and physical-chemical characterisation of the material periodically sampled during the aerobic biodegradation lasting 7 weeks was carried out. Specifically, investigations on biological stability degree, organic matter content and heavy metals total content and contaminant release in water phase (leaching behaviour) were performed.

Materials and methods

Sampling procedure

In this study waste materials were sampled in one of the four MBT plants operating in Rome whose maximum treatment capacity is 750 Mg MSW/day. Focusing on the biological treatment, after metal removal by belt-type electromagnetic separators, the biodegradable fraction (i.e. the undersize flow coming from the primary screening unit at 80 mm) is sent to a biostabilisation basin where an aerobic biodegradation occurs for 4 weeks at forced aeration conditions.

In order to evaluate the influence of longer duration of the aerobic biological process on SBW characteristics, the material was kept in the stabilisation basin 3 weeks more, therefore for a total duration equal to 7 weeks. One part of the stabilisation basin was isolated and set up in order to treat the material for 7 weeks and to allow the process monitoring and the material sampling, as well as to not hinder the normal operating conditions of the plant. Prior to the beginning of the biological process, the input material (untreated biowaste, SBW0) was sampled from the conveyor belt carrying the biodegradable fraction to the stabilization basin. Afterwards, during the aerobic biodegradation process, 7 samples of stabilised biowaste were progressively collected week by week. The 8 collected macro-samples were taken by collecting different increments along the conveyor belt (SBW0) and along the stabilisation basin (SBW1, SBW2, SBW3, SBW4, SBW5, SBW6, SBW7). After mixing and quartering, a final quantity of roughly 20 kg for each sample was sent to the laboratory for the biological and physical-chemical analysis. Then, a secondary quartering in lab was carried out in order to split an amount of 15 kg for the biological analysis, which needed as-received material, from the remaining amount of 5 kg which was air dried prior to perform all physical-chemical tests.

Analytical methods

Biological and physical-chemical characterisation of the material periodically sampled during the aerobic biodegradation lasting 7 weeks was performed to determine the following parameters: biological stability degree (determination of dynamic respiration index, DRI), organic matter content (determination of volatile solids, VS, and total organic carbon, TOC), heavy metal total content, contaminant release in water phase (leaching test).

The biological stability measures the degradability of the readily available organic matter contained in the waste in a short time period (1 – 4 days) under standardised aerobic conditions (Adani et al., 2004). In order to evaluate waste stability degree, a respirometric approach was used by determining the dynamic respiration index (DRI), namely the absolute maximum value of oxygen consumption due to microbial activity. DRI was measured and calculated according to the procedure reported in the Italian Standard UNI/TS 11184 (2006) by using a 30 l adiabatic respirometric reactor (Costech International Respirometer 3024).

The organic matter content was analysed by measuring the volatile solids (VS) and the total organic carbon (TOC). VS content was determined by loss-on-ignition at 550°C for 8 h (UNI, 2006) on about 5 g for each sample grinded to 0.5 mm and pre-dried at 105°C for 4 h. Total organic carbon (TOC) content was analysed by means of Shimadzu SSM-5000A instrument on approximately 0.2 g of air-dried sample grinded to size lower than 200μm (UNI, 2002). VS and TOC measurements were performed in triplicates for each sample.

Heavy metal content in solid materials (total content) was determined in triplicates by acid digestion according to the European Standards EN 15410 and 15411 (2011a,b) by making some changes. More specifically 3 ml of HNO_3 and 1 ml of HCl were added to 0.1 g of air dried sample grinded to 0.5 mm. Then the mixture was put in closed vessels (Parr Instrument Company - model 4744) and kept at 150 °C for approximately 15 hours. The obtained solution, after cooling, was firstly filtered by means of Whatman No. 41 filter paper so to separate residues and then it was dilute to volume with ultrapure water in 25 ml flask. A final filtration at 0.45 μm (Sartorius cellulose acetate syringe filters) was carried out in order to analyse the heavy metals in the solution by inductively coupled plasma atomic emission spectrometry (Varian ICP-AES).

For the leaching test, air-dried samples were grinded to a particle size lower than 4 mm, as required by the European Standard CEN 12457-2 (2002). A volume equal to 80 ml of deionised water was added to 8 g of each sample in order to obtain a liquid to solid ratio equal to 10 ml/g and bottles containing the mixture were stirred for 24 hours. Such test was conducted in duplicates for each sample. The obtained eluate, after decanting for 15 minutes, was firstly analysed by measuring the pH (Eustech Instrument pH 700). Afterwards, three steps of filtration were carried out: (1) centrifugation at 12000 rpm for 10 – 15 min (Thermo Scientific SL 16R Centrifuge), (2) vacuum filtration at 0.7 μm (Munktell AB glass fibre filters) and (3) final filtration at 0.45 μm (as required by the standard method) by means of syringe filters (Sartorius cellulose acetate filters). The dissolved organic carbon (DOC) (Shimadzu TOC-V CPH/CPN analyser) and the chloride content (Mohr's method; ISO 9297, 1989) were then measured in the filtered eluate. Prior to determine heavy metal concentrations, since the dissolved organic matter in the eluate caused interferences during ICP-AES running (as thereafter discussed), an acid digestion procedure was carried out according to APAT - CNR -IRSA Guidelines 29 (2003). Specifically, 1 ml of aqua regia was added to 10 ml of eluate and the mixture was put in the above mentioned Parr vessels and kept at 150 °C for 24 h. Then the obtained solution, after dilution to volume in 25 ml flask, was analysed by means of ICP-AES.

Results and discussion

Biological stability degree and organic matter content

Fig. 1 shows the results of the dynamic respiration index (DRI) measured for weekly samples during the biological process.

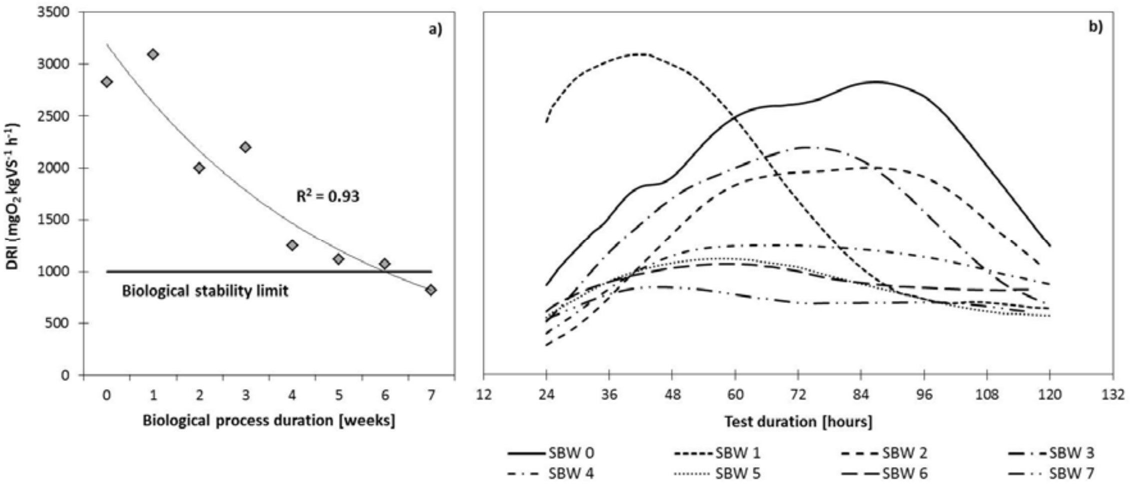

Fig. 1 a) Max DRIs trend and b) DRI trends hourly registered during the respiration test and averaged in 24 h

A progressive reduction of DRI, i.e. an increase of biological stability, during the biodegradation process was observed by following an exponential decreasing trend (Fig. 1a). Furthermore, DRI was found to be lower than the maximum limit equal to 1000 mgO_2 $kgVS^{-1}$ h^{-1}, below which the material is considered biologically stable (Adani et al., 2004), after 7 weeks of aerobic biodegradation (SBW7) with a percentage reduction equal to roughly 70 % comparing with non-stabilised waste (SBW0). It has to be noticed that DRI of SBW1 was slightly higher than DRI of SBW0. This is likely because the microbial activity and the related oxygen consumption, after one week of biodegradation, is still quite high and comparable to the beginning of the process whereas volatile solids, i.e. organic matter, slightly reduced (see Table 1). As a result, the area under the DRI curve of SBW0 was greater than that of SBW1 even if the latter had a higher max DRI (curve peak), as can be observed in Fig. 1b. The same was observed for samples SBW2 and SBW3. In other European Countries, such as Austria, biological reactivity of waste is analysed by means of a different type of respiration test which measures the cumulative oxygen uptake in 4 days (RA_4). Scaglia et al. (2010) found a correlation between the two respiration indices (DRI and RA_4) and derived the regression expression Eq. 1:

$$\mathrm{DRI} = (15.85 \pm 0.34) \cdot \mathrm{RA}_4 - (1.14 \pm 10.75) \qquad (1)$$

where DRI is expressed as mgO_2 $kgDM^{-1}$ h^{-1} and RA_4 as mgO_2 gDM^{-1}.

The Eq. 1 was used to calculate RA_4, given the DRIs found for all the samples as reported in Table 1. RA_4 values showed to be much higher than the maximum limit value equal to 7 mgO_2 g DM^{-1} set by the Austrian Landfill Ordinance (Binner et al., 2012), indicating a high reactivity of the material even after 7 weeks of biodegradation. It has to be pointed out that RA_4 limit is based on a longer duration of biological treatment as carried out in Austrian MBT plants, namely 2 – 6 weeks of intensive decomposition treatment plus a ripening phase ranging from 6 to 12 weeks (Tintner et al., 2010), unlike MBT plants of Rome.

Table 1 Results of biological stability indices and organic matter content

SBW samples	**DRI (mgO_2 $kgVS^{-1}$ h^{-1})**	**DRI (mgO_2 $kgDM^{-1}$ h^{-1})**	**RA_4 (mgO_2 gDM^{-1} h^{-1})^a**	**VS (% DM)^b**	**TOC (% DM)^b**
0	2826	1845.4	116.5 ± 1.9	65.3 ± 0.2	36.3 ± 1.0
1	3093	1699.6	107.3 ± 1.7	55.0 ± 1.0	28.4 ± 0.3
2	1999	1122.4	70.9 ± 0.9	56.1 ± 1.0	30.0 ± 1.1
3	2196	936.7	59.2 ± 0.6	42.7 ± 0.3	18.1 ± 1.6
4	1248	657.0	41.5 ± 0.2	52.7 ± 0.9	22.2 ± 2.2
5	1118	573.6	36.3 ± 0.1	51.3 ± 0.3	23.6 ± 0.9
6	1067	469.9	29.7 ± 0.04	44.0 ± 0.3	18.8 ± 1.1
7	819	354.5	22.4 ± 0.2	42.0 ± 1.3	14.8 ± 0.4
% reduction	70.0	-	-	35.7	59.2

^{a} Values calculated by means of Eq. 1; ^{b} Mean value ± standard deviation

Due to biodegradation, a reduction of organic matter content, in terms of TOC and VS, was observed with an approximately linear decreasing trend (Fig. 2a). The VS decrease was relatively low, especially comparing with the reduction found for DRI and TOC (Table 1). Furthermore for both VS and TOC the decreasing trend was not gradual (Fig. 2a). This is mainly because VS and TOC take into account the overall organic matter, including also non-degradable compounds (such as plastics) (Barrena et al., 2009) and the biodegradable fraction undergoing the biostabilisation process showed to be quite heterogeneous, being composed of not negligible percentage of plastics (roughly 10 %, Di Lonardo et al. 2012a). However TOC and VS showed to have the same trend (Fig. 2a) during the 7 weeks of biological treatment, as proven by the high linear correlation ($R^2 = 0.95$) found between the two parameters (Fig. 2b) since they are both direct indices of the organic matter content.

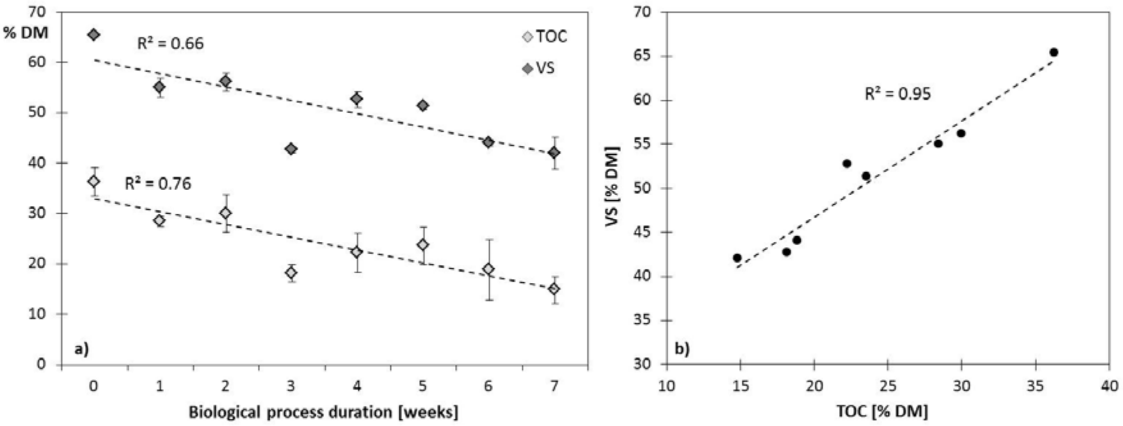

Fig. 2 a) Organic matter content (TOC and VS) trend during biological process and b) correlation TOC-VS

Heavy metals total content and leaching behaviour

Table 2 shows the results of heavy metals (HM) total content measured in the untreated biowaste (SBW0), in the stabilized biowaste after 4 weeks (which is the duration of the biological process in normal operating conditions of the MBT plant of Rome), as well as in the stabilised biowaste after 7 weeks of biological treatment (SBW7). The results are compared with limits reported by the European Commission document on biowaste (European Commission, 2001), by the Austrian Compost Ordinance

(BGBL, 2001) which identify the class B of compost as suitable for landfill cover, as well as by the Scottish Environmental Protection Agency (SEPA) standard (Baird et al., 2005) which states that “if mixed waste compost (i.e. stabilised biowaste) is able to achieve the indicative standard, then it may be possible to consider applying the material to land subject to risk assessment procedures on a site by site basis”.

Heavy metals do not degrade during the aerobic biological process (Richard and Woodbury, 1992), hence roughly constant concentrations might be expected. The obtained results showed some differences between the three analyzed samples (Table 2) and this was likely due to three main factors. Firstly, as mentioned above, the heterogeneity of the tested materials have a significant influence on the HM changes in concentration during the biostabilisation, as highlighted by the significant standard deviations. Furthermore, since most heavy metals are not volatilised at the temperatures occurring during aerobic stabilisation (50-70°C), the loss of mass due to degradation of organic matter may cause an increase of the heavy metal concentration in the biostabilised waste (Richard and Woodbury, 1992; Ciavatta et al., 1993; He et al., 1995; Zennaro et al., 2005; Dimambro et al., 2007; van Praagh et al., 2009). As a result, in the present work, metals showed to be more concentrated in the stabilised materials SBW4 comparing with SBW0, with the exception of Cd, Na and Si. Comparing SBW4 with SBW7, it can be noticed that most metals concentrations, unless Cr and Na, were lower in SBW7. This was probably due to metal loss through percolation (Whittle and Dyson, 2002; Amir et al., 2005; Castaldi et al., 2006), indicating that probably metals were transformed in more mobile forms during the last three weeks of biostabilisation. Comparing HM total content of SBW4 and SBW7 with limit values (Table 2), it can be seen that the latter fulfilled all the requirements whereas SBW4 showed exceeding of Cu, Ni and Pb content. Therefore, from this point of view (HM total content), stabilised biowaste after 7 weeks of biological process could be potentially utilised in environmental remediation applications (for non food production).

Table 2 Results of heavy metal total content in SBW0, SBW4, SBW7

	SBW samples			**EC doc**	**Austrian BGLB Compost Class B**	**SEPA**
Metals	**0**	**4**	**7**			
Al	9476.82 ± 1681.9	12375.5 ± 1389.4	10881.0 ± 593.2			
Ba	315.4 ± 21.1	396.1 ± 56.0	237.0 ± 19.5			
Ca	62895.8 ± 14207.8	68155.0 ± 13108.3	50467.3 ± 3992.6			
Cd	14.4 ± 6.0	1.7 ± 1.2	0.7 ± 0.1			
Co	2.8 ± 0.1	7.9 ± 2.7	3.0 ± 0.5			
Cr	25.9 ± 2.6	53.3 ± 13.2	56.1 ± 6.6	600	250	400
Cu	66.5 ± 21.3	1221.9 ± 616.7	90.8 ± 15.1	600	500	200
Fe	5371.9 ± 821.8	12025.7 ± 1043.8	8149.8 ± 435.0			
K	5791.2 ± 1124.2	7904.5 ± 607.0	7068.2 ± 428.9			
Li	5.2 ± 0.7	6.6 ± 0.7	5.4 ± 0.2			
Mg	3468.0 ± 497.5	4459.6 ± 694.3	3268.7 ± 146.2			
Mn	158.5 ± 24.1	584.3 ± 283.1	159.2 ± 6.9			
Na	5381.6 ± 806.7	5074.8 ± 364.0	5530.8 ± 485.6			
Ni	36.8 ± 62.7	593.5 ± 201.1	62.7 ± 11.4	150	100	100
Pb	219.0 ± 159.3	359.5 ± 69.0	153.8 ± 18.4	500	200	200
Si	117.6 ± 23.4	108.0 ± 62.8	89.1 ± 13.9			
V	17.1 ± 3.0	20.8 ± 2.0	17.3 ± 1.1			
Zn	272.0 ± 18.9	757.1 ± 204.2	382.9 ± 51.8	1500	1800	1000

Table 3 shows the results of pH, DOC and chlorides (mean ± standard deviation) measured in the elautes obtained by the leaching test performed on the different samples. In Italy, restrictions on waste leaching are set by the Italian Ministerial Decree 186/2006, established for the regulation of non-hazardous waste recovery and limit values for pH and chlorides are reported in Table 3. It has to be pointed out that stabilised biowaste is not counted in the list of non-hazardous waste that could be subjected to recovery procedure in the case of compliance with the limits.

The pH values did not vary significantly during the stabilisation process. However pH showed to follow approximately the characteristic trend of an aerobic biodegradation (Sirini et al., 2009), ranging from 5, at the beginning of the process, to 7, at the end of the process. DOC and chlorides globally reduced after 7 weeks of aerobic biodegradation comparing with untreated waste. Nevertheless they did not showed a progressive decreasing trend (as found for TOC and VS) likely because of the heterogeneity of the tested material. Furthermore Cl^- concentrations were much higher than the limit value set by MD 186/2006.

Table 3 Results of pH, DOC and chlorides measured in the elautes

SBW samples	pH	DOC (mg/l)	Cl^- (mg/l)
0	5.90 ± 0.01	2816.8 ± 294.8	1317.9 ± 119.2
1	6.55 ± 0.04	2123.6 ± 14.6	508.6 ± 18.7
2	6.60 ± 0.015	2147.5 ± 278.0	763.0 ± 71.8
3	6.63 ± 0.02	1589.0 ± 29.0	536.7 ± 32.5
4	6.59 ± 0.025	2400.8 ± 191.8	687.1 ± 77.2
5	6.65 ± 0.0	2394.0 ± 114.5	853.8 ± 8.1
6	6.72 ± 0.01	1736.8 ± 79.8	628.5 ± 16.1
7	6.77 ± 0.005	1835.5 ± 226.5	724.2 ± 49.3
Limit values	5.5 — 12	-	100

Prior to discuss the results regarding the metals leaching, an explanation on the choice to pre-digest the eluates in order to oxidise the dissolved organic matter, as described above, worth to be given. Fig. 3 shows the comparison between metal concentrations found in digested and not-digested eluates of SBW0, which showed to have the highest DOC concentration (see Table 3). It can be noticed that in the pre-digested eluate, for which a DOC breakdown of roughly 80 % was obtained, higher metal concentrations were measured, especially for micro-elements. This demonstrated the interference of the high concentration of dissolved organic matter during ICP-AES running which caused a “blinding” of the optical reading.

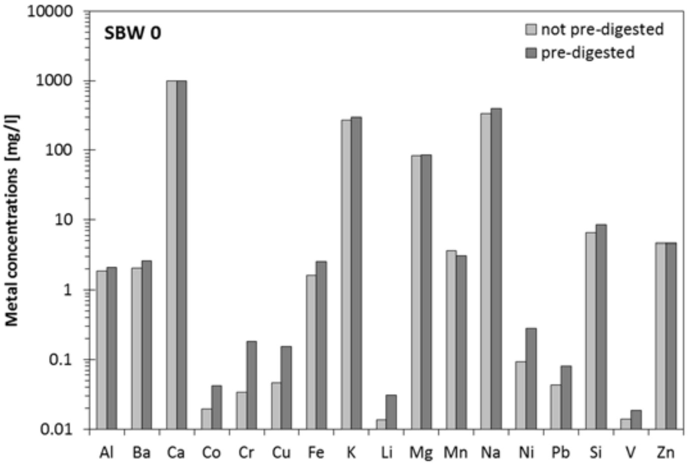

Fig. 3 Comparison between metal concentrations in digested and not-digested eluates of SBW0

Generally, regulations on composted/biostabilised waste set limits on total heavy metal content and restrictions on leaching behavior are not reported. The solely determination of the total composition does not provide useful information about the potential release of contaminants in the environment (van der Sloot et al., 2004), which could occur if, for example, waste are applied to land.

Table 4 shows the results of metal concentrations (mean ± standard deviation) measured in the eluates of each SBW sample, as well as limit values set by MD 186/2006. Firstly, it has to be noticed that in most cases the standard deviations were relatively high and this again can be related to the heterogeneity of the waste. Cadmium was lower than the limit of quantification, therefore was not reported. Leaching in water phase of Ba, Ca, Co, Cr, Li, Mg, Mn, Ni, and Si tended to decrease at the end of the process whereas that of Cu, Fe and Pb increased. Moreover Al, K, Na, V and Zn concentrations in the eluates of the weekly samples did not significantly vary. Comparing HM concentrations with limit values, only Co and V fulfilled the limit values set by MD 186/2006, hence, if stabilised biowaste was subjected to such regulation, it could not be recovered.

Table 4 Results of metal concentrations measured in the eluates

Values expressed in mg/l

SBW samples	**Al**	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**
0	2.11 ± 0.07	2.6 ± 0.13	991.5 ± 109.1	0.18 ± 0.02	0.15 ± 0.01	2.53 ± 0.38	300.2 ± 23.0
1	2.10 ± 0.02	2.15 ± 0.06	606.5 ± 14.6	0.08 ± 0.005	0.37 ± 0.02	2.39 ± 0.14	295.4 ± 72.7
2	2.28 ± 0.12	2.2 ± 0.15	482.4 ± 84.4	0.11 ± 0.005	0.31 ± 0.06	2.35 ± 0.1	285.8 ± 27.3
3	1.47 ± 0.09	1.88 ± 0.09	400.9 ± 24.3	0.30 ± 0.24	0.6 ± 0.03	2.87 ± 1.2	220.0 ± 10.4
4	2.52 ± 0.2	0.99 ± 0.001	489.9 ± 92.9	0.11 ± 0.03	0.73 ± 0.08	3.21 ± 0.39	322.9 ± 21.4
5	3.24 ± 0.17	0.92 ± 0.12	626.7 ± 64.8	0.15 ± 0.02	0.65 ± 0.03	5.04 ± 0.07	340.6 ± 9.8
6	3.24 ± 0.94	1.75 ± 0.16	486.9 ± 71.1	0.10 ± 0.007	0.65 ± 0.06	5.73 ± 0.16	282.2 ± 2.0
7	2.21 ± 0.137	1.42 ± 0.22	434.7 ± 32.4	0.08 ± 0.006	0.58 ± 0.002	4.4 ± 0.45	338.7 ± 0.6
Limit values	-	1	-	0.05	0.05	-	-

Week	**Mg**	**Mn**	**Na**	**Ni**	**Pb**	**Si**	**Zn**
0	85.8 ± 3.9	3.08 ± 0.05	401.7 ± 32.9	0.28 ± 0.04	0.04 ± 0.003	8.53 ± 0.88	4.63 ±0.07
1	55.3 ± 15.1	1.04 ± 0.001	308.9 ± 14.9	0.31 ± 0.02	0.1 ± 0.008	5.9 ± 0.1	3.47 ± 0.15
2	46.4 ± 5.8	0.99 ± 0.17	299.4 ± 33.4	0.14 ± 0.001	0.12 ± 0.01	5.25 ± 0.65	3.65 ± 0.48
3	43.3 ± 5.0	0.83 ± 0.1	246.1 ± 24.5	0.28 ± 0.15	0.23 ± 0.009	4.31 ± 0.55	6.62 ± 0.19
4	52.9 ± 7.1	1.12 ± 0.13	428.9 ± 122.6	0.29 ± 0.07	0.21 ± 0.03	3.41 ± 0.01	4.19 ± 0.03
5	66.7 ± 3.0	1.16 ± 0.03	419.8 ± 19.1	0.35 ± 0.006	0.29 ± 0.006	2.81 ± 0.02	4.01 ± 0.18
6	57.3 ± 3.3	0.84 ± 0.05	341.5 ± 9.4	0.31 ± 0.02	0.22 ± 0.03	4.5 ± 1.6	3.14 ± 0.23
7	50.2 ± 4.5	0.87 ± 0.08	395.2 ± 47.3	0.20 ± 0.02	0.24 ± 0.015	3.42 ± 0.44	4.38 ± 0.04
Limit values	-	-	-	0.01	0.05	-	3

Values expressed in µg/l

Week	**Co**	**Li**	**V**
0	41.8 ± 20.4	31.11 ± 12.74	18.50 ± 2.36
1	16.5 ± 1.2	15.2 ± 0.14	16.02 ± 1.67
2	17.4 ± 2.7	14.13 ± 1.43	19.75 ± 2.89
3	16.8 ± 3.2	12.84 ± 2.03	17.19 ± 2.92
4	18.4 ± 2.7	15.28 ± 0.05	27.14 ± 0.96
5	26.2 ± 1.4	19.14 ± 0.65	28.93 ± 0.63
6	16.7 ± 0.3	15.83 ± 0.78	23.55 ± 1.32
7	20.3 ± 1.5	12.46 ± 0.72	23.89 ± 1.90
Limit values	250	-	250

Organic matter influence on release of metals

The release of contaminants in water phase is generally governed by the variation in pH and heavy metals mobility, depending on each element, tends to be high at basic ($pH > 9$) and/or acidic ($pH < 4$) conditions (Whittle & Dyson, 2002; van der Sloot et al., 2004). Furthermore, in the organic matter rich matrices, as in the case of biowaste, the role of solid organic matter and dissolved organic matter (DOC), is a key factor in the transfer of inorganic contaminants to the water phase (van der Sloot et al., 2004; van Praagh et al., 2009). Since the pH of SBW eluates were found to be around neutral values (see Table 3), the release of metals was supposed to be minimally influenced by this parameter (Whittle & Dyson, 2002), therefore DOC was likely the most dominant factor controlling it (van der Sloot et al., 2004) by means of complexation reactions with metals (van Praagh et al., 2009).

Chromium, copper, lead, nickel and zinc were considered for the evaluation of organic matter influence on release since they are known to have a high affinity with organic carbon (Greenway & Song, 2002; Amir et al., 2005; Castaldi et al., 2006; van Praagh et al., 2009). Furthermore they are considered of greatest concern for a possible downstream environmental application because they are readily leachable and tend to bio-accumulate, causing short or long-term toxic effects to organisms in the environment (Richard & Woodbury, 1992; Whittle & Dyson, 2002; Castaldi et al., 2006).

In Fig. 4 the heavy metals and organic carbon percentage release calculated for samples SBW0, SBW4 and SBW7 are shown and compared. Such percentage release was calculated by means of the Eq. 2:

$$\% \text{ release} = 100 \cdot \mathrm{C}_{\text{leach}} / \mathrm{C}_{\text{sol}} \qquad (2)$$

where C_{leach} is the concentration measured in the eluates of the three samples and C_{sol} is the total content in solid materials. It can be observed that Cr percentage release decreased during the 7 weeks of stabilisation as it tends to be bound to organic solid matter and to insolubilise (Ciavatta et al., 1993; Greenway and Song, 2002). For the same reason at the 4th week of stabilisation Cu, Ni and Zn percentage release was lower comparing with the beginning. Then at the 7th week of aerobic biodegradation, the release increased likely because such metals tend to leach along with the dissolved organic carbon. Both Pb and organic carbon percentage release progressively increased from the beginning till the end of the process. Castaldi et al. (2006) reported, indeed, that changes in the water-soluble fractions of Pb were reflected in the water-soluble organic C concentrations.

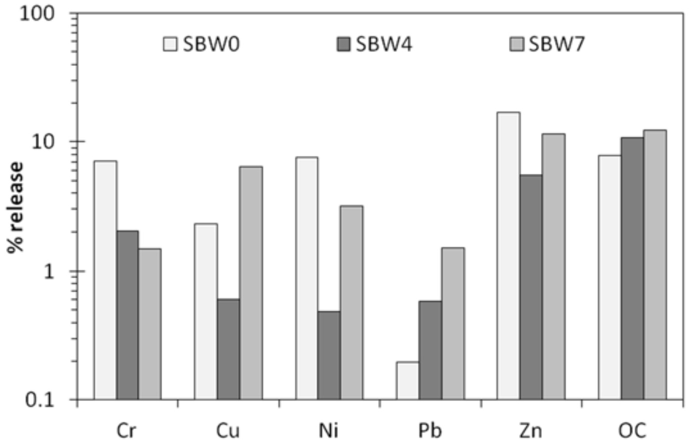

Fig. 4 Comparison of heavy metals and organic carbon (OC) percentage release between SBW0, SBW4 and SBW7

Conclusions

In the present work, the influence on stabilised biodegradable waste quality by extending the duration of the aerobic biological process from 4 weeks (which is the duration in normal operating conditions of the treatment) to 7 weeks was evaluated. Results showed that, after 4 weeks of biological treatment, the waste was still quite reactive. A good biological stability degree was reached at the end of the process, even if a further ripening treatment should be also investigated in order to possibly obtain a highly stabilised material. The metals total content in stabilised biowaste after 7 weeks of biological treatment was found to fulfil the requirements for a potential utilisation in environmental remediation applications (for non food production). Contaminants release in water phase showed to increase for some metals (e.g. Cu and Pb) during biostabilisation likely due to the significant affinity with the dissolved organic carbon. However, further investigations on leaching of contaminants (by means of pH dependence test and percolation test) need to be carried out in order to better understand release controlling mechanisms and to assess long term leaching behaviour, especially in view of a possible use in environmental remediation. Such evaluations could be useful in the development of a quality standard, currently lacking, which could identify the most suitable recovery or disposal in relation to the specific characteristics of the stabilised biowaste.

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