Comparative analysis of composting source separated biowaste and the organic fraction of the Chania MBT plant

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Abstract: For decades, the management of solid waste was a major problem for the Regional Unity of Chania, actually resulting in a conviction and fine by the European Court of Justice. This resulted into a concerted action for the fast development of a Mechanical Biological Treatment (MBT) plant, using composting as the biological step, in combination with a sanitary landfill, located in Korakia-Akrotiri.

The operation of the plant begun in 2005, with the goal to serve both as a Materials Recovery Facility (MRF) for the content of the blue bin, serving the collection of commingled recyclables, and a dirty MRF – composting plant, to divert the biodegradable fraction of the city's Municipal Solid Waste (MSW) from landfill.

The objective of this study focuses on estimating the biostability and maturity of the organic fraction from the MBT plant of Chania, as well as the organic fraction from the "Sorting at Source" program. Mixtures of the above two MSW organic fractions with green waste were composted for a comparative evaluation of the course of the composting process and the quality of the produced compost. For further evaluation of results, are additional analyzes physical and chemical parameters such as temperature, pH, electrical conductivity, moisture content, nitrogen, volatile solids.

Keywords: biowaste, MSW, composting process, maturity, stability

1. Introduction:

With the publication of the European Circular Economy Package in December 2015, the EU Commission paved the way for a resource efficient society and sustainable recycling industry across Europe. In a circular Economy, the organic fraction of waste is not allowed to landfill. Instead, through the composting process, it forms a resource for organic soil improvers, growing media component, and fertilizers. The carbon and nutrient contents of biowaste are mainly concentrated in the organic fertilizers, soil improvers, and growing media, or can be extracted or modified into a range of different bio-based products, too. All these secondary products can replace fossil-based products, such as mineral fertilizers, peat, and fossil fuels. After use, the residues of these products can flow back safely into the biosphere, thereby closing the carbon and nutrients cycles.

The composting process, when used for the treatment of organic wastes, primarily aims to produce a stabilised end-product with properties that could enhance plant growth. Alternatively, the composted product could be simply added to arid soils to increase soil carbon content (Komilis, 2010). Most researchers in their attempt to characterise the quality of compost very often use the terms maturity and stability (Lasaridi and Stentiford, 2001; Lasaridi et al., 2014). Maturity is a term related to the effect of composts to crops and indicates the presence or absence of phytotoxic effects. An immature compost is usually phytotoxic, mostly due to the production of organic acids (Epstein, 1997), and may have a negative impact to plant growth. Compost stability is a stage in the decomposition of the organic matter and is, therefore, a term to relate to the microbial decomposition or microbial respiration activity of the composted matter (Lasaridi and Stentiford, 1998). A high-quality compost should be both mature and stable. However, a stable compost is not necessarily a mature compost (Komilis, 2009).

The purpose of this research is to estimate the stability and the maturity of the produced compost from the MBT Plant of Chania and the compost that was produced from biowaste, which was collected from the "Sorting at Source" pilot program and to compare to their overall final quality.

For the complete evaluation of the process evolution and the final product quality, further analyses of physical and chemical parameters, such as temperature, pH, electrical conductivity, moisture content, volatile solids, Kjeldahl nitrogen, germination index, PAH, PCBs and heavy metals are conducted, according to the Hellenic law.

2. Materials and methods

Two different MSW organic fractions were used for this research. The first was biowaste from the new source separation program of the Municipality. According to the National Solid Waste Management Plan, 40% of the biowaste should be source separated by the year 2020. This pilot program started at the beginning of the year and serves large producers of biowaste such as the Technical University of Crete, and military units, expanding in the last three months to biowaste from the street markets. The second was the mechanically separated organic fraction from the MBT plant of Chania. The organic fraction of the mixed waste is separated in a secondary sieve and is directed through a conveyor belt to magnetic separation, to ensure, as far as possible, the minimum presence of ferrous materials in the organic fraction directed to composting. These two fractions were mixed with shredded green wastes, from the park and street pruning of the Regional Unity of Chania.

The first two piles were set up on 12/02/2017 and consisted of biowaste with green wastes at a ratio of 1:1 and 1:2 by volume, with a total volume of 6 m^3 each. The next two piles were set up on 21/2/2017 and consisted of the mechanically separated MSW organic fraction with green wastes at a ratio of 1:1 and 1:2 by volume, with a final volume of 6 m^3 each. All the materials were measured with a tank of 1 m^3.

2.1. Composting process and sampling protocol

The technique that was used for the composting process was the turned windrow. Turned windrows are passive piles which are turned frequently to maintain aerobic composting conditions; in this case the frequency of turning was determined by the temperature profile of the pile. Windrow composting is considered as a dynamic, low cost but extensive system. The frequent turning promotes uniform decomposition as the cooler outer layer of the matrix is moved inside the mass where the material is exposed to high temperatures and intensive microbial activity.

The temperature of the piles was recorded every 3 days with a digital thermometer; in the results section the mean of the pile temperature at the six monitoring points for each pile is reported. Each time the pile temperature declined, the mixtures were turned with a compost turner. If needed, water was added during turning.

Sampling was scheduled on the first day and every two weeks. Samples of approximately 0.5 kg were obtained from five different points in the pile. The procedure followed was according to ELOT EN 12579: Soil improvers and growing media- Sampling. In the piles with the mechanically separated MSW organic fraction, inert contaminants, like plastics, metals, etc, were present. Therefore, during sampling, all the inert materials were removed to avoid damage of the laboratory equipment.

2.2. Physical and chemical analysis

For the determination of the moisture content the ELOT EN 12048 method was followed, according to which a test portion is dried in the oven at 105±2 ^{o}C overnight and moisture is calculated on the basis of the resulting mass loss. For the determination of the organic matter, a test portion dried at 105±2 ^{o}C is burned in a muffle furnace at 540 ^{o}C for 4 hours. The organic matter is taken to be the loss of mass on ignition.

The pH was determined using a sample extracted with water in an extraction ratio of 1:5 (v/v). The same method was followed for the electrical conductivity according to ELOT EN 13038. For the nitrogen content the method describing in ELOT EN 13654.01 was followed.

3. Results and discussion

Although the composting process was not fully completed at the time of writing this paper, several useful observations were obtained. The available results indicate that the four mixtures have similar properties and composting process evolution.

Figure 1 illustrates the temperature and pH profile of the four mixtures during the composting process. The temperature profile includes the oxidative-thermophilic phase and the mesophilic phase. There was a rapid establishment of the thermophilic phase and the peak temperature (50 °C) was reached at about 20 days from the initiation of the process for all piles, apart from mixture 4 that the peak temperature was reached at about 45 days. This is attributed to the presence of easily degradable matter. Small increases of the temperature were observed after each turning of the piles. These temporary increases are attributed to the better aeration of the pile during turning, although they might be also related to the moisture correction of the piles; in any case they indicate that some material within the pile was still readily biodegradable.

The pH (Fig. 1) increased to alkaline ranges is attributed to the consumption of protons during the decomposition of volatile fatty acids, the generation of CO_2 and the mineralization of organic nitrogen (Beck-Friis et al., 2001; Smars et al., 2002). Alkaline pH is desirable since it limits the availability of heavy metals (Tiquia, 2005); on the other hand, it can induce a micronutrient deficiency (Rosen et al., 1993). Actually, very alkaline pH values can limit the development of plants and cultivations.

Figure 1. Temperature and pH variation with time in the four piles during the composting process

Figure 2 shows the water content variation in the four piles. The moisture steadily declined during the composting process, due to the evaporation induced by the temperature increase and the turning of the material. Despite the generation of some water by the biochemical process of the organic matter decomposition, there is a net water loss during open composting.

In all piles, a moisture content of less than 40% was observed after 90 days of composting, which is the threshold value suggested by Icontec (2003) to designate stability. Thus values below that limit would indicate a stable material, according to the abovementioned standard. However, low moisture content at the early stages of the process can severely limit the biological activity, leading to a poor real stabilisation of the final product, while the induced temperature drop may also provide a false indication of stability. Therefore, the moisture drop, as an indication of stability should be used with high caution and only in combination of other indices of the process evolution. Respirometric tests (to be carried in the next stages of this research) are the most suitable for assessing stability, as they include mechanism to counteract for the various factors that may limit microbial activity before the assimilation of all readily available organic matter in the waste (Lasaridi and Stentiford, 1998, 2001; Lasaridi et al., 2014).

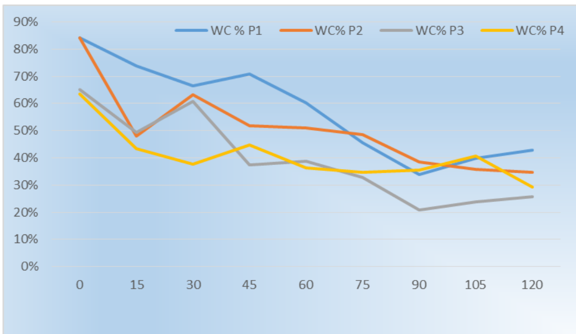

Figure 2. Water content variation with time in the four piles during the composting process

Figure 3 presents the volatile solids content variation during the composting process. All the mixtures at the beginning of the process had a VS content of about 85%. The VS content dropped with composting time for over 3 months, as the organic matter was mineralised. After about 100 days of processing a stabilisation in the VS content is observed, indicating the decomposition of the easily degradable organic substrates.

According to Raj and Antil (2011) a material can be considered stable as long as a higher than 42% VS reduction takes place. In the 120 days of composting that were monitored here, the VS reduction is about 30% for all four mixtures.

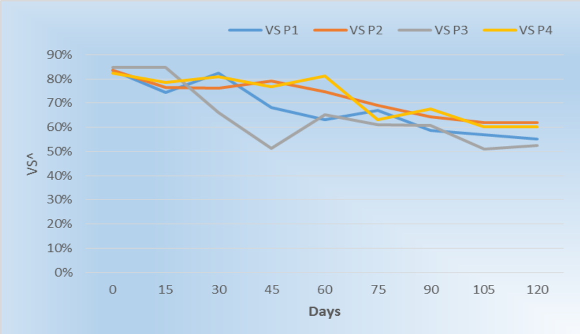

Figure 3. Volatile solids variation with time in the four piles during the composting process

Figure 4 illustrates the variation of the carbon and nitrogen content during the composting process. The reduction of carbon content was mainly due to the oxidation of organic matter to carbon dioxide by the microorganisms. At the same time, TKN seems to follow the reverse route than carbon, indicating increased concentration in all four piles. This indicates that nitrogen loss during the process was limited, possibly due to the modestly thermophilic temperatures reached. Moreover, the decomposition of the organic matter results in a reduction of the mixture mass, which may lead to an increase in the concentration of other substances, such as nitrogen in this case, if they are not extensively lost during the process.

Figure 5 illustrates the variation of the C/N ratio for the four piles. The C/N ratio has been extensively used in the literature as both a stability and maturity indicator during composting (Said-Pullicino et al., 2007; Tognetti et al., 2007); however, widely variable values of C/N ratio have been reported in studies attempting to determine the stability and maturity of composts. Some examples are: <17 (Moldes et al., 2007), <12 (Bernal et al., 1998), around 15-16 (Barral et al., 2007), between 15 and 20 (Rosen et al., 1993). Other authors support the idea that it is not possible to establish one unique C/N ratio value indicating stability, since this depends on the characteristics of the material under treatment (Defrieri et al., 2005).

The observed C/N ratios (<15) for the four mixtures after day 105 indicate that at that stage the material in all four piles was stabilised to a similar level and fulfilled the criteria of stability and maturity that have been proposed with regard to that parameter.

Brewer and Sullivan (2003) reported that the C/N ratio itself is not an appropriate index of stability, but it is necessary to illustrate its development during the process, rather than use a unique threshold value. In this study, the C/N ratio declined for all four mixtures from values in the range of 30-35 at the beginning of the process to below 15 after about 3.5 months of processing, indicating no practical differences in the four mixtures. Nowadays, there seems to be a general consent in the literature that the C/N ratio should be combined with other analytical tests and indices in order to characterise the stability and maturity of composts.

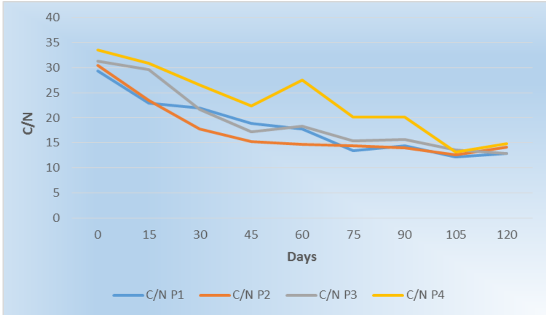

Figure 5: C/N ratio variation with time in the four piles during the composting process

4. Conclusions

Although the composting process has not been completed yet, especially regarding the maturing phase, neither the full set planned analyses has been completed, the results obtained so far for the parameters examined: (i) do not indicate differences in the performance of the process for the different mixtures; (ii) do not support the necessity of a higher fraction of green waste in the mixture, which can facilitate the operational design of a full-scale facility, as green waste are not abundant in the area; and, (iii) cannot clearly identify if the material has been sufficiently stabilised and matured.

The next phase of analysis is the determination of the variation of values of the germination index as well as more specialised analyses, such as heavy metals content, microbiological tests and organic toxic compounds (PAHs and PCBs) according to the requirements of National and European regulations.

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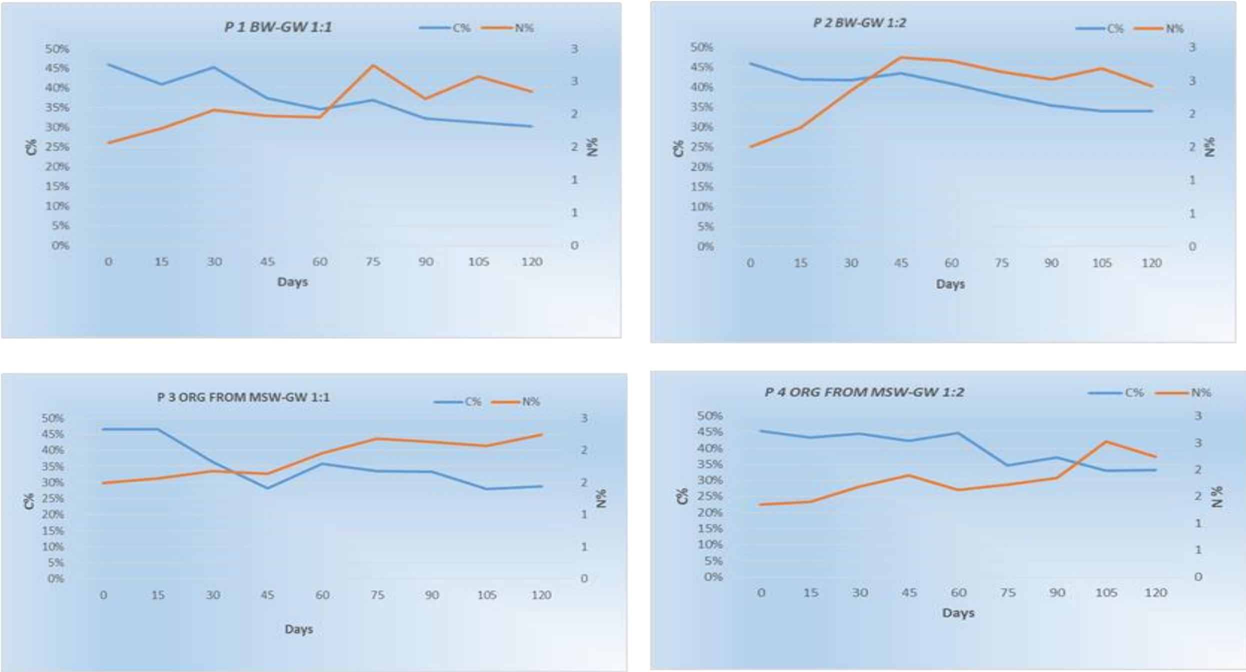

Figure 4: Carbon and Nitrogen variation with time in the four piles during the composting process

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