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Research article

Study and assessment of segregated biowaste composting: The case study of Attica municipalities

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ABSTRACT

This work aims to assess the operation of the first large scale segregated biowaste composting scheme in Greece to divert Household Food Waste (HFW) from landfill and produce a material which can be recovered and used as compost. The source separation and collection of HFW was deployed in selected areas in Attica Region serving about 3700 households. Sorted HFW is collected & transported to the Mechanical and Biological Treatment (MBT) plant in Attica Region that has been designed to produce Compost Like Output (CLO) from mixed MSW. The MBT facility has been adjusted in order to receive and treat aerobically HFW mixed with shredded green waste in a dedicated composting tunnel.

The composting process was monitored against temperature, moisture and oxygen content indicating that the biological conditions are sufficiently developed. The product quality was examined and assessed against the quality specifications of EU End of Waste Criteria for biowaste subjected to composting aiming to specify whether the HFW that has undergone recovery ceases to be waste and can be classified as compost. More specifically, the heavy metals concentrations (Cr, Cu, Ni, Cd, Pb, Zn and Hg) are within the set limits and much lower compared to the CLO material that currently is being produced at the MBT plant. In regard to the hygienic requirements of the product it has been found that the process conditions result in a pathogen free material (i.e. *E. Coli* and *Salmonella*) which does not favor the growth of viable weeds and plant propagules, while it acquires sufficient organic matter content for soil fertilization. Noticeable physical impurities (mainly fractions of glass) have been detected exceeding the quality control threshold limit of 0.5% w/w (plastics, metals and glass). The latter is related to the missorted materials and to the limited pre-treatment configurations prior to composting.

The above findings indicate that effective source separation of biowaste is prerequisite for good quality production and marketing of compost and special consideration should be made to minimize glass impurities prior composting (i.e. awareness raising and pretreatment stage). Therefore, it is feasible to gradually replace the production of questionable quality CLO in MBTs with biowaste compost which is in line with the required quality control standards especially when heavy metals concentrations is concerned.

1. Introduction

Household Food Waste (HFW) receives considerable attention worldwide due to the environmental, economic and social impacts it generates. HFW constitutes the largest production source among the different food waste sectors (manufacturing, food service/catering and wholesale/retail), while it also comprises the largest single waste fraction generated by households (reaching up to 50% of total household waste). Future trends show that HFW is anticipated to increase significantly due to population growth and increasing consumption patterns giving rise to increased environmental impact in cases when unsustainable management techniques are applied.

The putrescible nature of HFW is related to the increased level of readily available organic compounds to microorganisms and its high water content (75–95%) making the efficient MSW

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management challenging. Source separation and collection of HFW is a common practice, applied especially in EU countries, aiming to divert and treat HFW in biological treatment facilities (i.e. composting, anaerobic digestion); however, in many other countries HFW landfilling remains the predominant waste management option, since limited initiative is taken in regard to the application of national policies and technologies for HFW management. In all regions where separate collection schemes have been introduced they are regarded as a successful waste management option for boosting HFW recycling and recovery effectiveness, while enhancing the recycling rate of other MSW streams and the calorific value of residual MSW.

The objective of this work is to present the findings of the first large scale application of source separated biowaste composting in Greece aiming to evaluate the process and compare the compost against quality standards and Compost Like Output which is currently produced in Mechanical Biological Treatment (MBT) facilities.

2. Materials and methods

2.1. Biowaste source separation & treatment scheme

The HFW source separation program was performed in selected areas of two municipalities in Attica region (Athens and Kifissia Municipalities). In the case of Athens Municipality a road container system was applied in a highly populated residential area (208 inh/ha) and in a commercial area (54 inh/ha) including about 80 large producers (e.g. restaurants, bars) covering around 2000 households. In Kifissia municipality a door to door collection scheme was set out in low to medium density residential areas (20–70 inh/ha) serving approximately 1700 households. Each municipality uses a single waste vehicle to collect and transport sorted HFW 2 to 3 times per week covering all participating areas.

The collected HFW (about 370 tons per year) is transferred and unloaded on a weekly basis to the reception area of the MBT in Attica Region for aerobic biological treatment. Green waste from public areas of Attica municipalities is also delivered by competent local authorities and temporarily stored for further processing. Part of green waste is used as bulking agent (about 35 tons per year) in order to enhance the aerobic biodegradation process of segregated HFW. The reporting period of biowaste management scheme is 18 months.

2.2. Pre-treatment and composition of feedstock

At the MBT facility sorted HFW undergoes manual removal of non-biodegradable materials (e.g. plastics) and other pollutants (mainly bulky impurities), which may adversely affect the process of composting, the quality of the final product and potentially cause damage to the mechanical equipment of the composting unit. Green waste undergoes size reduction using a shredder aiming to modify its physical properties and facilitate mixing with sorted HFW. The use of shredded green waste as bulking material is related to its water absorption capacity for adjusting organic mixture humidity level, to the reformation of the substrate's structure and porosity, to the adjustment of the carbon to nitrogen ratio of the feedstock (Seo et al., 2004; Eklind and Kirchmann, 2000; Haug, 1980) and its availability and proximity to the processing unit (Schaub and Leonard, 1996). The mixing ratio of HFW to green waste was set at 1:3 on volume basis in order to achieve the following initial conditions for the substrate; moisture content between 60 and 70%, TOC:TN between 25 and 35 and physical properties that will maintain the required aerobic conditions in the composting process.

2.3. Composting unit

The organic waste streams collected from the municipalities are loaded to a conveyor belt feeding the homogenizer for materials mixing. Then through a second conveyor the organic mixture is led directly to one of the MBT's composting channels bypassing the mechanical separation system of the plant. The nominal capacity of the MBT facility is 1200 tons/day of mixed MSW serving municipalities of Attica Region. The composting unit comprises of 48 closed composting channels (80 m $\times$ 5m $\times$ 2.8 m each) for treating the organic fraction of mechanically sorted mixed MSW. One of these channels was used exclusively for the treatment of sorted HFW. The organic substrate is loaded from one side of the channel in a continuous mode while the mechanical agitator mixes and shifts the substrate periodically from the loading to the discharge point. The agitator is equipped with water addition devices through which the stirred material is simultaneously hydrated in order to maintain humidity at desired levels. Aeration of the material is performed from the bottom of the channel through negative aeration in the initial zone (active composting) and positive aeration in the next zone (maturation) depending on the different stages of the composting process. The post-treatment process involves screening of the composted material in order to obtain a homogenous particle size product.

2.4. Measurements & data collection

Data collection was performed for the physicochemical characterisation of biowaste (sorted HFW and green waste) and the quality control evaluation of the produced compost. Additionally, measurements were carried out spatially along the composting channel for temperature, moisture content, oxygen concentration, bulk density and organic matter content in the MBT plant. In this way, profiles were obtained for each of the above parameters as a function of process time. For this purpose, four zones were defined along the composting channel, in which measurements were made and can be related to process time. The data collection was performed by measuring a wide variety of parameters, as presented below. Temperature and oxygen content was recorded using the oxygen hand measuring device CM 37. The water content was determined after drying the collected samples at 105 °C for 24 h. The pH and conductivity were measured according to EPA Method 9045D using a pH-meter (Mettler Toledo MPC 227 pH/Conductivity Meter). Total Organic Carbon (TOC) was determined using TOC analyzer TOC-VCSH of Shimadzu coupled with Solid Sample Module – 5000A. Volatile Solids (VS) (Organic Matter) were measured by weight loss on ignition at 550 °C for 4 h. Total Nitrogen (TN) was determined through digestion (Gerhard Kjeldaltherm KB/KBL), distillation (Gerhard Vapodest Distillation) and titration, as described in the German Standard Methods for the examination of water, sewage and sludge (DIN, 1993). Total bulk density (BD) was determined according to Thompson et al. (2002), method 03.03-C. The total concentration of heavy metals (Cr, Cu, Ni, Cd, Pb, Zn, Hg) was determined using fast sequential atomic absorption spectroscopy (Varian AA240FS). The value of each parameter is presented as an average of a triplicate measurement. Sampling of sorted HFW was based on the methodology described in Malamis et al. (2015). Substrate sampling was performed with the guidelines of European Committee for Standardization (CEN) standard "Sampling of liquid and granular waste materials including paste-like materials and sludges", parts 1–5, (CEN, 2001). Finally, compost sampling was performed according to EN 12579:2013 'Soil improvers and growing media – Sampling'. All measurements and analyses were made in the ISO17025 certified laboratory of the Unit of Environmental Science & Technology.