Study of carbon balances from organic waste in a decentralised composting facility in Tinos Island

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Introduction

The necessity to comply with the European legal framework has reinforced the need for sustainability in the field of municipal waste management. During the last decades efforts have been focused on the development of systems that promote the waste hierarchy in management methods, highlight the responsibility of the various involved parties and especially, incentivize public participation. In particular, separating waste at source at the time of their generation, apart from making waste generation visible, also represents a key driver on the way of sustainable practices and towards implementing zero waste approaches. From an in an economic, environmental and social point of view and taking into consideration the fact that the fraction of biowaste could amount up to half of the total municipal solid waste generated (Hoornweg & Bhada-Tata, 2012), the benefit of diverting the specific waste fraction from landfills, is evident (USEPA, 2014). Biowaste as a resource has been acknowledged as key element of the future EU policy, moving towards a circular economy and holds great potential for the production of alternative added-value products, if treated in a safe manner. For the case of Greece, 1% of biowaste generated is attributed to the respective industrial activities, 13% to commercial facilities and food services, while the amount of biowaste generated at household level is 86%. In particular, food waste is the predominant fraction (76%) of biowaste.

Large quantities of food waste from the household sector also mean high costs for collection and transport, as well as for separation and treatment in waste management facilities.

The need for sustainable and efficient treatment of biowaste takes more serious dimensions in the case of Greek island regions since these territories possess some 'weaknesses' directly related to their geographical specificities. The demands here become more pressing due to limited natural resources, restricted access to key infrastructures and services, high transportation costs, low population density, seasonal variations of waste flows due to tourism, limited land availability, non-favourable economies of scale and fragility of the environmental ecosystems. Common current practices observed in the majority of Greek rural areas, including islands, is that biowaste are still landfilled or burned on-site, resulting in major odour nuisances, visual impact, human health and environmental hazards (Manios, 2004). The absence of appropriate infrastructure, the limited recycling initiatives, the lack of environmental public awareness and the fact that involved management costs usually exceed available funds pose a significant problem on local authorities who are primarily responsible for waste management. Scarcity on data collection and inconsistent information on biowaste quantities and composition is another critical issue as data availability is considered of major importance for establishing any environmental policy and sound waste management plans.

To this direction, the present study focused on the implementation of an integrated solid waste management scheme for municipal biowaste in an island region (Tinos island, South Aegean Prefecture), taking into consideration the principle requirements and waste hierarchy priorities set in the EU legislation (Landfill Directive 99/31/EC and Waste Framework Directive 2008/98/EC).

Methodology

The pilot scheme which was applied in Pyrgos and Panormos, comprising two communities of Tinos island (i.e. 400 inhabitants approximately), was based on source separation and on-site management in a prototype composting unit, with the aim of turning biowaste back into valuable product (compost), as well as contributing to the overall sustainable local development of the area. A bring scheme collection system was employed, including 30 biowaste collection points' network, located in the periphery of the communities. The pilot scheme foresaw that the participating

population should separate their biowaste at source (i.e. household, shop, restaurant, public building etc.) using specific indoor equipment (i.e. kitchen caddies and biodegradable starch-based bags) and subsequently dispose them to corresponding outdoor wheelie bins of greater capacity (120 L). Collection and transport of biowaste was performed by a satellite vehicle, which operated at regulated frequency in order to transfer the pre-sorted organics to an innovative, prototype, composting unit. The prototype composting unit was constructed and installed within the study area, in order to reduce transportation costs, be manageable, compact and low cost in comparison with similar commercial systems, minimize contamination risk of pre-sorted biowaste and thus produce high quality compost.

The materials have been analysed on an input-output basis for their elemental composition, moisture content, heavy metals concentrations, ash content and heating values. In all cases, the corresponding technical standards have been followed as described by Vakalis et al. (2016). In addition, mass balances have been implemented and the different flows have been assessed. The scope of this analysis is the calculation of the carbon balances and of the carbon conversion during composting. Ultimately, this approach can be a useful environmental management tool for the determination and the minimization of the greenhouse gases production.

Technology innovation

The innovative design and operational features of the prototype composting unit include the following: the feeding compartment acquires an appropriate lifting mechanism in order to facilitate the loading and unloading of the source sorted biowaste within the bioreactor (total volume of 21 m3). The composting process follows four successive stages in a continuous mode, with a retention time of the substrate of 20-60 days (min. 20 days if the maturing phase takes place outside the bioreactor). Moreover, the prototype unit has three innovative automated operations. The aeration system is ensured by a blower attached to a piping system which runs along the bioreactor at appropriate positions, providing the necessary air supply to the organic mass. The hydration system consists of three branches of plastic water pipes with regulating flow for each stage of the composting process through an electromechanically operated valve. The deodorization system includes a system for the suction of flue gases from the interior of the bioreactor to the biofilter, so as to avoid possible nuisances during the operation of the unit.

The monitoring of the integrated biowaste management scheme was performed in three levels:

- raw biowaste fraction (i.e. biowaste generation quantities; compositional analysis studies in order to evaluate the effectiveness of the source separation (<1.5% impurities ratio); recording of seasonal variations (winter, spring, summer, autumn); biowaste physicochemical characteristics, considering basic parameters such as pH, conductivity, moisture content, bulk density, C/N ratio, organic matter, heavy metals and nutrients content. The study was oriented in this direction since the determination of the organic feedstock characteristics for the in-vessel prototype unit can provide valuable information on the evolution of the composting process and the quality of the final product (compost) as well.
- monitoring and evaluation of composting process using specific parameters such as temperature, aeration, moisture content, organic matter, pH and EC evolution.
- Physicochemical characteristics of the final products (composts), as well as of the hygienic (Salmonella sp. & E.coli) and biological parameters (i.e. phytotoxicity – plant response, content of germinable seeds and plant propagules), as set in the End-of-Waste criteria for biodegradable waste subjected to biological treatment (compost & digestate).

Regarding the conclusions of the present study, the following could be highlighted:

- Source separation is of significant importance, especially for the sensitive MSW fraction of biowaste, since separately collected organics exhibit high purity levels so as to facilitate any further treatment and thus the products received (compost) have better quality and greater value.
- The recorded low impurities content (~2-3%) demonstrate that the participating households practice effectively the source separation of the generated biowaste.
- The physico-chemical and biological characteristics of the final product satisfied the limits set by EoW 2014 for biodegradable waste subjected to biological treatment (compost & digestate):

  - No pathogens

  - Low heavy metals content in comparison with compost produced from mixed waste collection
- The prototype composting unit can receive greater quantities of biowaste so as to operate at its maximum capacity and accomplish the full optimization of the composting process. This can

be achieved by incorporating additional communities in the separate biowaste collection scheme.

- Biowaste as the largest MSW fraction should be treated on-site, following the proximity principle as much as possible. Therefore, the proposed decentralized composting system could offer a sustainable solution for remote communities in order to demonstrate 'closing of the loop' biowaste management models, that can improve local farming practices, reduce nutrient leaching and provide protection of the important natural assets.

Waste management continues to be a timeless problem for Greece. The island regions, which are closed, sensitive systems are further burdened compared to the mainland by the application of non-rational management practices (uncontrolled disposal of MSW). International experience has shown that the sorting at source of municipal biowaste combined with the appropriate treatment technologies can be a viable alternative for the comprehensive solution of the problem with multiple socio-economic and environmental benefits. Consequently the proposed, pilot, biowaste system was evaluated as an efficient, integrated and decentralized approach to island regions and may constitute a sustainable model to islands like Tinos, and other remote areas to use the particular geographic characteristics as advantages and opportunities, overcoming permanent structural disadvantages.

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