LIFE CYCLE ASSESSMENT OF ORGANIC WASTE COMPOSTING

EVALUAREA CICLULUI DE VIAŢĂ A COMPOSTĂRII DEŞEURILOR ORGANICE

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Abstract. *Organic waste represents an issue that needs to be solved in order to achieve sustainable development. In Romania, organic waste (biodegradable) represents almost half from the household waste composition. The waste management in Romania is characterized by the continued growth of waste quantities and landfilling continues to be the main elimination method for solid waste. Composting and anaerobic digestion are two solutions for reducing of organic waste landfilled. In this paper life cycle assessment (LCA) methodology was applied to determine and evaluate the environmental impact of composting system. All LCA phases were performed: goal and scope definition, inventory analysis, impact assessment and interpretation. Two LCA tools were used for the evaluation: GaBi software and Life Cycle Assessment - Integrated Waste Management Assessment Tool. The results reveal that the quantity of waste composted and the type of waste are influencing the environmental impacts values.*
Key words: environmental impacts, life cycle, organic waste

Rezumat. *Deşeurile organice reprezintă o problemă care trebuie să fie rezolvată pentru realizarea dezvoltării durabile. În România, deşeurile organice (biodegradabile) reprezintă aproape jumătate din compoziţia deşeurilor menajere. Managementul deşeurilor în România este caracterizat printr-o continuă creştere a cantităţii de deşeuri, iar depozitarea continuă să fie principala metodă de eliminare a deşeurilor solide. Compostarea şi digestia anaerobă reprezintă două soluţii pentru reducerea deşeurilor organice depozitate. În această lucrare metodologia de evaluare a ciclului de viaţă (ECV) a fost aplicată pentru a determina şi analiza impacturile asupra mediului a sistemului de compostare. Toate etapele ECV au fost realizate: definirea obiectivului şi domeniului de aplicare, analiza de inventariere, evaluarea impacturilor şi interpretarea. Au fost utilizate două instrumente ECV: software-ul GaBi şi Evaluarea ciclului de viaţă - instrumentul de evaluare a managementului integrat al deşeurilor. Rezultatele au arătat că cantitatea de deşeuri compostată şi tipul de deşeu influenţează valorile impacturilor asupra mediului înconjurător.*
Cuvinte cheie: impacturi de mediu, ciclul de viaţă, deşeuri organice

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INTRODUCTION

Waste management is becoming more challenging than ever (Elwan *et. al*., 2015). Methods like composting and anaerobic digestion are most used in solid waste management, playing an important role in treating, minimizing, and utilizing organic wastes produced by municipalities (Aziz *et. al.,* 2016; Ghinea *et. al*., 2012; Sarkar *et. al.*, 2016). Composting is a biological process in which organic matter is decomposed and stabilized under certain conditions (Vigneswaran *et al*., 2015). This method can be successfully applied for treating of organic waste which represents the fraction with the highest percentage in the composition of household waste (Ghinea and Gavrilescu, 2015). In the last years several studies which investigated the organic waste composting from environmental point of view were performed. Only a few of them are presented below:

- Reeh and Moller (2001) compared aerobic composting and anaerobic digestion of organic waste considering a number of environmental effects and energy balance, nutrient recycling, global warming potential etc.;

- mineral fertilizer and compost production, transport of them and cultivation stage were evaluated with life cycle assessment (LCA) methodology by (Martínez-Blanco *et. al.,* 2008), showing that compost production has the biggest impact for all the categories studied;

- municipal solid waste composting was included in an integrated waste management system and evaluated from environmental view by (Ghinea *et. al.,* 2012);

- comparisons of environmental impacts of two compost product forms: powder and granular were performed using LCA by (Aziz *et. al.,* 2016). They concluded that granular compost had a higher impact on the environment than powder regarding global warming potential (GWP) category while other impact categories were similar (acidification potential (AP), eutrophication potential (EP), human toxicity potential (HTP) and photochemical oxidation potential (POCP)) (Aziz *et. al.,* 2016).

In this paper the environmental impacts of composting process are determined and evaluated by applying two LCA tool.

MATERIAL AND METHOD

1. Description of the studied process

Composting is a process of decomposition and humification of organic waste performed under aerobic conditions at 50 – 60 ^{o}C. In the municipal waste stream the organic waste consists mainly of organic household waste and garden waste (Andersen, 2010). The organic matter contained by solid waste is break down by the microorganisms resulting valuable humus (Andersen, 2010; Veeken *et. al*., 2011). This is an organic soil improver that stimulates plant growth, it is free of pathogens and seeds, and does not attract insects and worms, and also can be stored without producing bad odours (Veeken *et. al.,* 2011). Composting is energy consuming and implies greenhouse emissions. Gases like CO_2, CH_4, N_2O, VOC, NH_3 are emitted during the microbial degradation of organic waste (Andersen, 2010; Cadena *et. al.,*

2009). There are various composting facilities, in table 1 are presented some characteristics of windrows, composting cells and closed tunnels.

Table 1

Short characterization of different composting facility (Veeken *et. al.*, 2011)

	Windrows	Composting cells	Closed tunnels
Capacity (ton/year)	2.500 – 150.000	2.500 – 300.000	**20.000 – 300.000**
Composting time	8 - 9 weeks	8 weeks	**3 weeks**
Composting stages	4 weeks pre-composting, 4 weeks post-composting	3 weeks pre-composting, 5 weeks post-composting	**1 week pre-composting, 2 weeks post-composting**
Aeration	Pressure aeration	Negative aeration	**Pressure aeration**
Air treatment	Membrane cover filtrates air	Air cooling (outside air or water) and by filter	**Scrubber and biofilter**
Composting reactor	**Aerated windrows covered with a membrane**	**Composting cells, with an aeration floor**	**Closed tunnels, aeration floor, recirculation of process air**

The composting process evaluated in this study included the following steps: mechanical pre-treatment, composting, maturing and soil application.

2. Life Cycle Assessment (LCA)

Life-cycle assessment (LCA) is a methodology which can be used for environmental assessment of facilities, processes, services, and products from raw material extraction through manufacturing and use to end-of-life (Ghinea C., Gavrilescu M., 2010). Four major phases are necessary to be performed in order to conduct an LCA study (Ghinea, 2012; ISO, 2006): goal definition and scoping, inventory analysis, impact assessment and interpretation. There are many tool developed based on LCA methodology, only two of them are used in this study: GaBi software and LCA-IWM (life cycle assessment- integrated waste management) Assessment Tool (fig. 1).

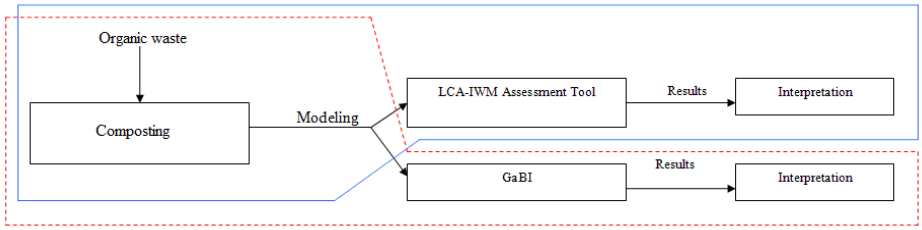

Fig. 1 Schedule of evaluation of composting with LCA-IWM Assessment Tool and GaBi software

LCA-IWM Assessment Tool was specifically developed for life cycle analysis of waste management by den Boer *et. al.* (2005) while GaBi software represents one of the most popular software tools for LCA. If the first tool is an Excel model with a Visual Basic graphical interface which has modules representing individual waste management processes such as Temporary Storage, Collection, Transport and Treatment, the second one allows rapid modeling even of complex processes and for different production options (Ghinea, 2012). LCA-IWM Assessment Tool is based only on the LCA CML 2001 method, while GaBi include and other methods like Eco-Indicator 95, Eco-Indicator 99, EDIP 1997, 2003, ReCiPe and others. In this study only CML 2001 will be considered for evaluation, in order to compare the obtained results with these two instruments. The list of impact categories used is presented in table 2.

Table 2

List of impact categories used

Methodology	Impact categories	Abbreviation
CML2001	Abiotic Depletion Potential	**ADP**
	Acidification Potential	**AP**
	Eutrophication Potential	**EP**
	Global Warming Potential	**GWP**
	Human Toxicity Potential	**HTP**
	Photochemical Ozone Creation Potential	**POCP**

RESULTS AND DISCUSSIONS

The functional unit considered for this study was 10.000 t of organic waste composted. During composting operations the total fuel consumption was estimated at 5.53 L per tonne of waste. The electricity demand for composting is 10 kWh/t, while water demand is 2% from input mass. Waste water represents 125 L/t input, while the fresh compost contains 50% water (Ghinea *et. al.,* 2012). The emission factors for the composting process were also considered (CO_2, CH_4, NH_3, organic carbon etc.). The fresh compost quantity resulted from composting process is 72.2% from organic waste composted (Ghinea *et. al.,* 2012). Based on these, the results obtained after modeling the composting process with the two tools presented above can be compared only in terms of CML 2001 methodology (LCA-IWM Assessment Tool gives the results according to CML 2001). Figure 2 illustrates the environmental impacts generated by composting process evaluated with LCA-IWM Assessment Tool, while fig. 3 presents the environmental impacts obtained after evaluation of the same process with GaBi software. The results obtained are in person equivalents (PE). It can be observed that all impact categories studied have positive values which mean negative impacts on the environment. The impact categories values obtained with LCA-IWM Assessment Tool are higher than those obtained for the same impact categories with GaBi software. A hierarchy of categories of impact can be made in order of decreasing environmental impact: AP>EP>GWP>ADP>POCP>HTP (fig. 2) and

AP>EP>POCP>GWP>HTP>ADP (fig. 3). It can be observed that AP and EP are the impact categories most affected by the composting process.

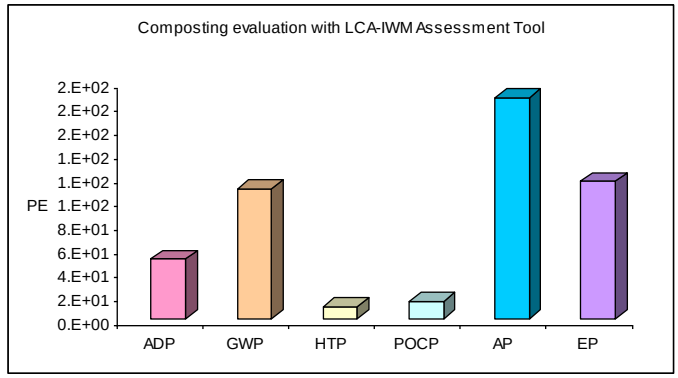

Fig. 2 Environmental impacts generated by composting process determined with LCA-IWM Assessment Tool

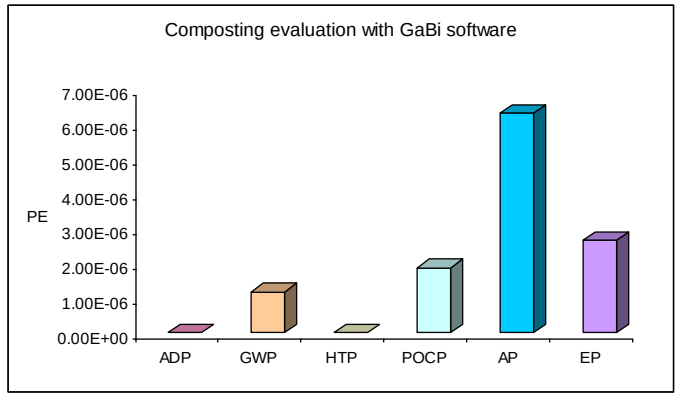

Fig. 3 Environmental impacts generated by composting process determined with GaBi software

CONCLUSIONS

1. LCA methodology was applied for determination of environmental impacts caused by organic waste composting.

2. The evaluation was performed using LCA-IWM Assessment Tool and GaBi software and only the results obtained with CML 2001 method were presented.

3. It can be concluded that composting process have negative impacts on the environment but not highest as in the case of waste landfilling. Therefore, the composting process can be successfully used in the treatment of organic waste.

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