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Research article

Greening MSW management systems by saving footprint: The contribution of the waste transportation

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A B S T R A C T

Municipal solid waste (MSW) management constitutes a highly challenging issue to cope with in order of moving towards more sustainable urban policies. Despite new Standards call for recycling and reusing materials contained in the urban waste, several municipalities still use landfilling as a waste disposal method. Other than the environmental pressure exerted by these plants, waste transportation from the collection points to the landfill needs a specific attention to correctly assess the whole burden of the waste management systems.

In this paper, the Ecological Footprint (EF) indicator is applied to the actual MSW of the city of Palermo (Sicily). Results show that the effects produced by the involved transportation vehicles are not negligible, compared to those generated by the other segments of the waste management system.

This issue is further deepened by analysing the role of transportation in an upgraded waste management system that is represented by the newly designed waste management plan of Palermo. The computed saved ecological footprint is used here for suitably comparing the environmental performances of the MSW system in both scenarios.

Finally, the suitability of the EF method to address not only complete waste management plans but also single segments of the waste management system, is also discussed.

1. Introduction

The European Union (EU) is strongly committed to improving waste management with the aim of contributing to reduce health and environmental problems. The priority goals of the EU waste policy are set in the 7th Environment Action Programme (European Parliament, 2013) and call all Member States for a reduction of the amount of waste generated; a maximization of recycling and reuse; a limitation of incineration to non-recyclable materials; and a progressive limited use of landfilling to only non-recyclable and non-recoverable waste.

More recently especially in 2015, the European Commission adopted a package to support the transition toward a circular economy (European Commission, 2015), in which what is used to be considered a waste (i.e. something to be discarded) it is regarded as a valuable resource instead. Therefore, waste management play a central role in a circular economy. The circular economy package establishes, in fact, a long-term path for the improvement of waste management and recycling, with long-term targets to reduce landfilling and increase recycling and reuse. In more detail, it has included four legislative proposals on waste (European Parliament and of the Council, 2015a, 2015b; 2015c, 2015d) that amend previous EU's waste legislation, especially the following legal documents: Waste Framework Directive (i.e. Directive 2008/98/EC on waste); Landfilling Directive (i.e. Directive 1999/31/EC); Packaging Waste Directive (i.e. Directive 94/62/EC); Directives on end-of-life vehicles, on batteries and accumulators and waste batteries and accumulators, and on waste electrical and electronic equipment (WEEE) (i.e. Directives 2000/53/EC, 2006/66/EC, and 2012/19/EU, respectively).

Among the targets set in the above-cited waste proposals, there are the followings:

- the share of municipal waste prepared for reuse and recycling up to 60% by 2025 and 65% by 2030;
- gradual limitation of the landfilling of municipal waste to 10% by 2030.

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A more comprehensive overview of the targets set by the waste proposals is presented in a briefing report concerning the EU Legislation in Progress of the February 2017 (European Parliament, 2017).

In order to improve the urban waste management, so fulfilling the EU waste policy's targets, the impact of municipal solid waste (MSW) management systems on the environment should be properly considered by local administrators. The availability of easy and reliable methods for assessing the impact of these systems becomes therefore essential. Based on a literature review, the Life Cycle Assessment (LCA) methodology (ISO, 2006a; ISO, 2006b) is one of the methods that are mostly used for this purpose. A good review of the LCA studies of MSW management systems is presented in Laurent (Laurent et al., 2014a, 2014b).

Generally, a MSW management system may be subdivided in the three following phases: collection, transportation and waste treatment (thermal, biological and mechanical pre-treatments and landfilling). The effectiveness, by an environmental point of view, of MSW management systems strongly depends on the level of separate collection: a limited disposal in landfill will result in small amounts of the released greenhouse gases (Calabrò et al., 2015; Calabrò, 2009). The environmental sustainability of entire waste management systems is an issue that is currently evaluated by researchers all over the world (Rigamonti et al., 2016), particularly their energy consumption and their return performances (Tomić and Schneider, 2017). However, most of the attention seems to be turned either to the final steps of the chain, namely waste treatments, or to the initial ones, i.e. the collection. Nabavi-Pelesaraei et al. (2017a) pointed out the attention on the energy and environmental performances of incineration and landfilling of MSW; Widomski et al. (2017) specifically considered the sustainability of landfilling processes; Rimaityte et al. (2010) analysed the sustainability of the solid waste incineration as the crucial phase for defining optimized waste management systems. Other authors (Chi et al., 2015) considered the collection of MSW by a life cycle assessment point of view, particularly analyzing the importance of a source-separated collection for the whole total environmental performances of a MSW system. The energy and environmental impact of the recycling of MSW has been investigated, by virtue of its evident importance in the life cycle perspective of the waste management systems (Nabavi-Pelesaraei et al., 2017b).

Actually only a limited attention seems to be paid on the transportation of waste from the urban pick-up points to landfills. In this respect, the study of Pérez et al. (2017) presented a calculation, using the LCA methodology, of the impact produced by the vehicles involved in the waste collection on the climate change. Economopoulou et al. (2013) analysed the role of the waste transportation in a region comprising 113 municipalities, having in mind the minimization of the annualized capital investment and of the annual operating costs of the complete waste treatment chain of the waste treatment. By comparing costs and profits of a waste management system, Das and Bhattacharyya (2015) indicated the minimization of the waste transportation routes as an effective tool for reducing waste collection and transportation costs. Another critical factor associated to waste transportation that has to be considered is the traffic jam that interferes with the flow of the fleet that is aimed at this service. Ismail et al. (2012) used the linear programming method to define the best route that is able to meet the maximum saving of cost.

On the contrary, the transportation of waste is actually quite a relevant segment of the entire waste management system that needs proper consideration in order of correctly assessing the whole burden of the municipal waste management. In fact, it could remarkably affect the value of the pressure exerted by the complete waste system. For instance, the fraction of the municipal waste of the city of Palermo that is transferred to the landfill is handled by garbage trucks whose pollutant releases cannot be ignored since the average trip of each of them is approximately 12 km. In addition, the urban circulation of garbage trucks can be responsible for traffic flow's delays, especially when passing through the high number of roundabouts on the path from the urban downtown to the landfill (Corriere et al., 2013; Peri et al., 2013). This induces an increase in the pollutant emissions that in turn implies a deterioration of the urban air quality.

Apart the analysis of the role of the transportation of waste, it must be noted that, recently, the scientific literature is showing an increasing interest for aggregate indicators, able to catch, in a synthetic way, the environmental burden of the human activities. Carbon, water and ecological footprints are the most used indicators in this sense.

The Carbon Footprint (ISO, 2013) would measure the CO_2-equivalent emissions caused by processing activities It is relevant that this method enables the evaluation of direct (on site) and indirect (off-site) pollutant releases (Galli et al., 2012; Fang et al., 2014; Restrepo et al., 2016).

An effective overview of the urban carbon footprint (UCF) has been presented by Lombardi et al. (2017) that recognize UFC as one of the more valuable tools to apprise decision makers about city environmental sustainability. Shaikh et al. (2017) showed that water and carbon footprint analysis could be viable for investigating national electricity production scenarios. The relationship between ecological footprint and the calculation of the carbon footprint has been analysed by pointing out the role of the net carbon sequestration capacity of forest ecosystems (Mancini et al., 2016). The solid waste treatment and disposal has been recently approached using the carbon footprint method (Malakahmad et al., 2017), with an attention to the pollutant emissions from a landfill located in Selangor State (Malaysia). Finally, the carbon footprint has been used to propose an emergy-based analysis of different household solid waste management scenarios in Pakistan (Ali et al., 2018). Concerning specific segments of the MSW chain, carbon footprint has been applied for analysing the energy and biogas production from incineration and landfill in the UK (Jeswani et al., 2013). In this paper, the role played by MSW transportation on the environmental impact exerted by a whole management system is analysed using the holistic approach provided by the Ecological Footprint (EF) method (Wackernagel and Rees, 1996). This integrated sustainability indicator is, in fact, able, due to its intrinsic structure, to easi evaluate and compare not only the differences in terms of environmental impacts between, for instance, landfilling and recycling, but also the contribution provided by different stages of the whole chain. Specifically, the method was applied to the MSW management system of the city of Palermo (Southern Italy).

This in-field application of the EF method to a MSW management system further allows enriching the few applications of the EF that are referred to urban waste (Herva and Roca, 2013; Herva et al., 2014). The majority of them focuses, in fact, on other types of waste: construction and demolition waste (Simion et al., 2013; Marrero et al., 2017), urban animal waste (Li et al., 2012) and agricultural waste (Bian et al., 2010). By synthetizing, the aim of the present paper is twofold. From one hand, it explores the role of transportation in the working chain of the urban waste management; on the other hand, it provides a contribution for applying integrated assessment approaches such as the carbon footprint (and the Ecological Footprint, in particular) to the waste management systems.

In addition, this application might be useful in order of assessing the suitability of the EF method - as an integrated approach - for the urban policies' analysis.