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LANDFILL MINING: A CASE STUDY ON CHARACTERIZATION OF EXCAVATED WASTE *

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Abstract

Landfilling has represented the dominant method for municipal solid waste (MSW) disposal during the recent decades. Therefore, the recovery of materials from landfills through landfill mining is proclaimed as an innovative method to address these challenges. The excavation, processing, treatment and recycling of deposited materials is mainly referred to the economic aspects and to the reduction of the re-landfilled fraction of the waste. The main objective of this work is to describe a case study of sampling and characterization of excavated waste of a potential landfill mining site in Peccioli - Pisa (Legoli Landfill). Approximately at 10 m depth, the samples were collected from two layers of waste of different ages (2001 and 2007). Manual sieving and sorting into different waste fractions was performed. All the fractions were characterized in terms of total solids and total volatile solids and Biochemical Methane Potential test. Anaerobic tests were performed to evaluate methane production coming from landfilled waste, in particular referring to the residual biodegradable fraction contained in the municipal waste. Results show that the composition of the two excavated waste analyzed are quite different due to the waste management system used in that years. This factor affects methane production that resulted respectively 115 Nm^3 CH_4/ton e 47 Nm^3 CH_4/ton for 2001 and 2007.

Keywords: biochemical methane potential, landfill mining, waste characterization

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1. Introduction

Recently, concerns about resource and land scarcity have resulted in a renewed interest in historic landfills. In this context, the new concept of “Enhanced LandFill Mining” (ELFM) proposed by Jones et al. (2013) has originated. In particular, ELFM regards landfills not as a final solution but as temporary storage facilities from which the landfilled waste will eventually be valorized by means of recycling and incineration. This will result in improved recycling, increased re-use rates and optimized energy valorization (EU Directive, 1999; Jones et al., 2013; Van Passel et al., 2013).

Essentially, ELFM includes the combined and integrated valorization of waste streams as both materials (Waste-to-Material, WtM) and energy (Waste-to-Energy, WtE), while respecting stringent ecological and social criteria (Jones et al., 2013; Bosmans et al., 2013). One of the main drivers of ELFM is the valorization of waste materials excavated from landfills. Due to the heterogeneous nature of the waste streams in landfills, separation and treatment of the different waste streams are required to enable the generation of valuable recycled materials.

The main objective of this work is to describe a case study of sampling and characterization of excavated waste of a potential landfill mining site in Peccioli - Pisa (Legoli Landfill). At the beginning, all mixed MSW was landfilled in Peccioli; however, during the 2000s source separation (biowaste, paper and cardboard, glass and metals) gradually increased in this region and since the end of that decade, only the residual fraction of MSW has been landfilled (the percentage of separate waste collection in Tuscany passed from 13% in 2000 to 60% in 2015).

The specific aim of this study was to evaluate the feasibility of sampling landfill bodies and to analyze the samples in order to characterize their properties and thus provide information for post-landfill monitoring and operation.

The objectives of the field test were to:

- analytically characterize the composition of excavated waste;
- assess the variation in composition for each specific waste type;
- investigate the impact of storage time on the composition and characteristics of the waste;
- make an assessment of the valorization potential of the materials stored in the landfill.

4. Materials and methods

Approximately at 10 m depth, the samples were collected from two layers of waste of different ages (2001 and 2007). Manual sieving and sorting into different waste fractions was performed. All the fractions are characterized in terms of total solids (TS) and total volatile solids (TVS) and Biochemical Methane Potential (BMP) test. Anaerobic tests were performed to evaluate methane production coming from landfilled waste, in particular referring to the residual biodegradable fraction contained in the municipal waste.

Sorting was based on visual inspection, and thus small particles, which could not be identified visually, were classified as fine fraction. Each category was weighed separately. For analytical purposes the samples were shredded (A11 IKA, M20 IKA) into three size fractions, except bulky materials which were not processed (e.g., metals and stones).

The sorting was done within 7 days, while the analytical sample was stored for 1–2 months at ambient temperatures (below 0 °C) prior to analysis (Sormunen et al., 2008).

The rest was sieved and sorted manually into 7 waste categories (Table 2), namely paper and cardboards (PCB or hereafter referred to as “paper”), plastic (P), wood (W), metal (M), textiles (T), inert (I) and fine fraction (<10 mm).

One of the most important parameters in USEPA estimation model is the methane generation potential (L_0) which can be determined for any degradable waste by Biochemical Methane Potential (BMP) assay, which is a commonly accepted method used for waste characterization and estimation of ultimate methane amount produced under anaerobic conditions (Sel et al., 2016; Mou et al., 2014; Pearse et al., 2018).

Anaerobic biodegradability assays were performed for at least 90 days in order to determine the biogas (gas sum GS, Cossu and Raga, 2008) and the final methane (BMP_f) production of the evaluated substrates. The analyses were conducted using a modified method of Pecorini et al. (2012) following the basic guidelines and advice included in Angelidaki et al. (2009). The test was performed in triplicate for each sample using stainless steel batch reactors (1 L, 2 bar proof pressure). The vessels were incubated in a water bath at 37 °C and tightly closed by a special cap provided with a ball valve to enable the gas sampling (Pecorini et al., 2017). In order to determine the methane production, the methane content of the gas was then measured by using an IR gas analyzer (ECOPROBE 5 – RS Dynamics) and a microGC (INFICON) for residual production. As such, the BMP was calculated as the cumulated methane production (sum of the daily methane productions), divided by the TVS content contained in each batch (Pecorini et al., 2016).

5. Results and discussion

Different compositions were found by the manual sorting (Table 1). From the sampling it has been possible to observe how the fine fraction represents the degraded part of the organic unsorted waste component. The fine fraction is higher in the 2001 sample probably because the 2007 sample is a mechanically shredded dry waste. It can be notice that in 2001 no mechanical pretreatment was realized before the landfilling. Indeed, the percentages of metal is about 3% while in 2007 sample was equal to 0% probably due to a treatment of electromagnetic separation. The presence of the inert fraction is higher in 2007 sample; this fact can be a consequent of more precautionary request of local authority in the daily cover depth.

Table 1. Compositions of excavated waste in studied years

Fraction/composition (%)	***2001***	***2007***
Fine fraction	25	17
Green waste and wood	8	3
Plastic	19	21
Textiles	10	13
Paper	23	18
Inert	12	28
Metal	3	0

In Table 2 BMP_f values are reported based on specific TVS content and tons of sample waste. The biodegradable fractions were analyzed separately and mixed together depending on their percentage composition. It can be observed that the contribution in terms of methane production of single fraction is comparable in both samples. For this reason, the BMP_f of whole samples were mainly affected by the composition.

Results show that the composition of the two excavated waste analyzed are quite different due to the waste management system used in that years. This factor affects methane production that resulted respectively 115 Nm^3 CH_4/ton e 47 Nm^3 CH_4/ton for 2001 and 2007. The mechanically shredded dry waste (2007 sample) gives a methane production which is less than 59% compared to the 2001 sample. While the fine fraction of the 2001 sample is predominantly composed by incompletely biodegradable fraction, in case of 2007 sample it is evident that the fine fraction was composed by daily cover of soil due to low BMP_f.

Table 2. Compositions of excavated waste in studied years

Fractions	***2001***		***2007***	
	BMP_f		***BMP_f***	
	[NL CH_4/kg TVS_{sub}]	*[Nm^3 CH_4/t]*	*[NL CH_4/kg TVS_{sub}]*	*[Nm^3 CH_4/t]*
Fine fraction	211	110	204	22
Green waste and wood	209	68	105	63
Textiles	151	84	169	117
Paper	237	121	289	140
Mix Sample	221	115	-	47

For the sake of brevity, in Fig. 1 and Fig. 2, the cumulative biogas and methane productions of the 2001 sample are shown, as the 2007 sample curves are similar in shape and kinetics. Fig. 1 illustrates the differences between the results in terms of BMP of all fraction which compose the 2001 sample separately and the global contribution of mixed sample (with the percentual composition report in Table 1).

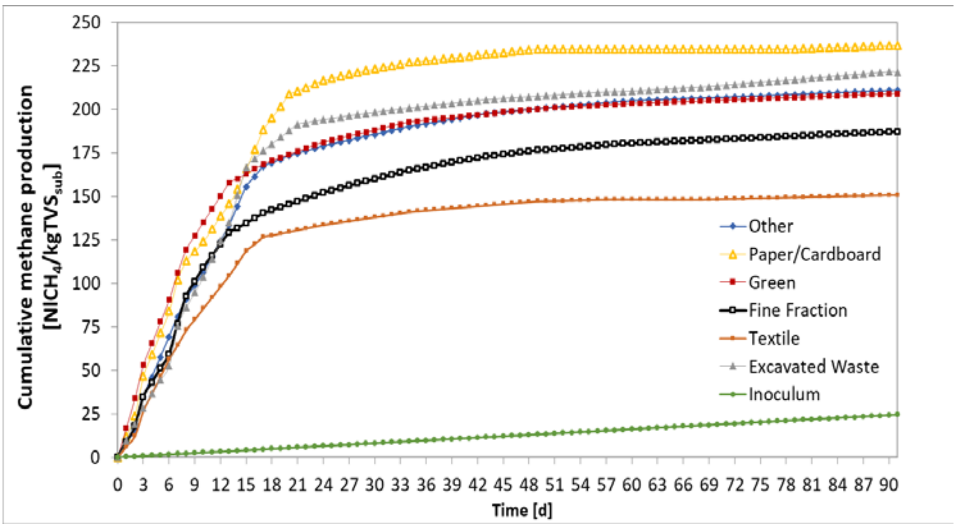

Fig. 1. Comparison of different BMP of waste categories (2001 sample)

Fig. 2 illustrates the differences between the results in terms of GS of all fraction which compose the 2001 sample separately and the global contribution of mixed sample (with the percentual composition report in Table 1).

Figures show as the highest specific production of methane and biogas was detected in paper biodegradability assays. The green waste and wood present a significant production of biogas while the textiles present a low contribution.

The BMP_f and the GS of whole 2001 samples of excavated waste result similar to the weighted average obtained with the single contribution per percentage composition.

As a point of reference, the German landfill ordinance (AbfAblV, 2001) requires that waste in MBT should be stabilised to a level such that its gas production potential as measured by a standardised method (GB21) should be <20 Nl/kg TS over a period of 21 days. On the basis of the present BMP assays (the method has some differences compared to GB21 test) and the assumption that 50% of biogas production would have been carbon dioxide (data not shown), no samples would have attained the maximum permissible value (<20 Nl/kg TS), indicating that waste had not yet been stabilised to this standard in either landfill. The production obtained for the 2001 sample was comparable to a biogas production of an organic fraction of MSW (Pecorini et al., 2012).

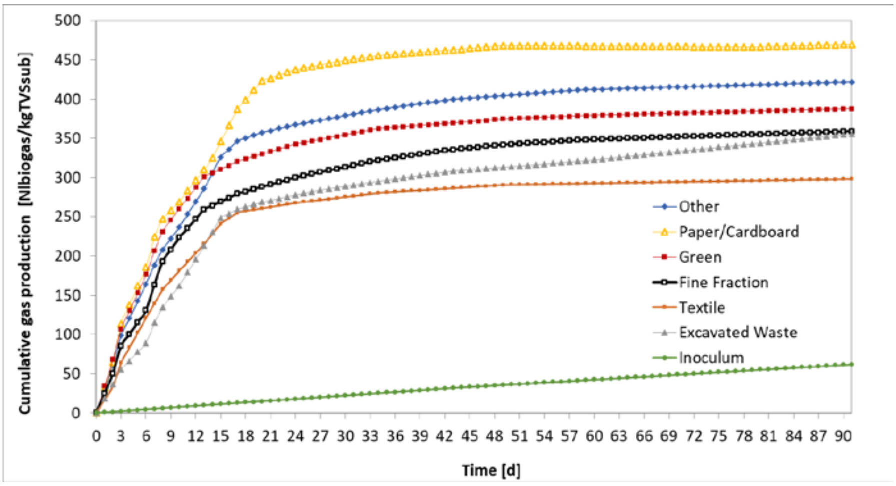

Fig. 2. Comparison of different GS of waste categories (2001 sample)

6. Concluding remarks

The methodology applied to sample and characterize the wastes from an MSW landfill used in this study can be used in other possible landfill mining sites.

On the basis of the biochemical methane potential assays, it resulted that waste had not yet been stabilised in the landfill, which was probably due to low moisture content of excavated waste (data not shown). In conclusion, waste sampling is a feasible way of characterising the landfill body, despite of the high variation observed and the fact that the minimum number and size of samples cannot easily be generalized to other landfills, due to different methods of waste management and different landfilling histories.

Based on the characteristics of the individual fractions separated from the waste, the valorisation options were assessed. During full scale excavation of the landfill, a specific treatment plant will be designed to treat and separate the waste which could result in different characteristics. For industrial waste, a detailed mechanical sorting can be convenient in "an end of waste" recovery approach to improve the calorific value.

Future studies on the stabilization of the excavated fine fraction (with high values of biodegradability) could be carried out in order to ensure eligibility for landfilling (refilling) or material recovery.

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