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Energetic efficiency of landfill: An Italian case study

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Abstract

An energetic analysis of an existing landfill for municipal solid waste was performed concerning the period from 2010 to 2014. The amount of energy recovered, of energy consumed, of waste disposed together with their composition, the amount and the quality of the landfill gas generated were monitored during this period. The amount of waste disposed ranged from about 80,000 tonne/year to about 200,000 tonnes/year. Correspondently the landfill gas collected increased from about 2,000,000 Stm^3/year to about 4,000,000 Stm^3/year. The amount of energy recovered resulted on average 1.4 kWh/ Stm^3 corresponding to an average amount of energy recovered per tonne of waste of about 43 kWh. Among the energetic consumptions a predominant role was played by the leachate treatment. Leachate production resulted characterized by a strong variability with a minimum of about 18.600 m^3 for the 2012 and a maximum of about 45,000 m^3 for the 2014 requiring from 11.7 kWh to 13.2 kWh of electrical energy per each tonne of waste disposed of.

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Keywords: Energy recovery, landfill gas, municipal solid waste

1. Introduction

Landfill is one of the most diffused solutions for final disposal of waste both in the EU and in other areas [1]. On the other hand landfill represents also an environmental concern due to the pollutant potential of liquid and gaseous emissions generated mainly by the spontaneous degradation of biodegradable components [2-6]. Due to these

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aspect landfill has to be managed with the aim of limiting the level of pollutant emissions to values that are considered sustainable by the current legislation [7]. The management of these emission requires materials and energy but can also lead to renewable energy production. In particular the landfill gas (LFG) is one of the most important emissions from landfill. In the EU-15, the contribution of LFG emissions to the whole anthropogenic greenhouse gas (GHG) production is of about 3% [3]. On the other hand LFG is also credited as renewable energy able to substitute fossil fuels. In fact, LFG is a mixture mainly of carbon dioxide and methane in quite similar concentrations [3], along with traces of other gasses such as H_2S, H_2, N_2O and NH_3, arising from the degradation of biodegradable materials. These materials are represented mainly by the organic fraction (OF) (*i.e.* residues of kitchen from household, restaurants and similar activities). Even if big efforts have been performed in the last years for the implementation of a zero waste approach and strategies, a large amount of biodegradable waste will still generated in the next years and disposed of in landfill [8-11]. Some of the component of LFG, such as CH_4 and N_2O, have a GHG potential significantly higher than the same mass of CO_2. They can reach very high concentrations as the methane (*e.g.* CH_4 >40-45 % v/v) or represent in any case a relevant environmental concern even at low concentration (*i.e.* N_2O). In fact, methane has a GHG potential 28 times higher than CO_2, whereas N_2O, even at typical concentrations << 1% v/v, gives a relevant contribution to this phenomenon due to its GHG potential of 310 times higher than CO_2. On the other hand, due to its origin and its high content in methane, the landfill gas represents also a renewable energetic source able to give a relevant contribution to the achievement of the Europe 2020 and 2030 goals [12,13]. In a previous study [11,14] was detected that an excessive pre-treatment of the waste aimed to reducing its biological reactivity and hence the emissions potential before dispose of in landfills equipped with LFG recovery, can reduce the whole environmental benefits. This result was a consequence of direct and indirect emissions generated by the pre-treatments and by the incidence of the energetic consumption for pretreatments related to the one recovered from the LFG. Other authors investigated the effects of pre-treatment on the amount of LFG generated assessing also the emissions due to its energetic recovery [15-19]. All these results showed that a large part of research activity was focused mainly on the energetic recovery from the landfill gas neglecting other relevant energetic consumptions necessary for the landfill management. In fact, landfill consist of complex and different activities as waste handling by wheeled loaders, climate conditioning of office building, leachate treatment, requiring energy and fuels. In the present study the data concerning the last five years of operation of an existing Italian landfill have been analyzed and presented. The landfill was chosen due to its particular features concerning both energy recovery and emission treatment. In fact, as imposed by National and EU legislation it is equipped with a landfill gas and leachate collection systems. The landfill gas is burned as fuel in a combined heat and power (CHP) plant whereas the leachate is processed in an *in-situ* treatment facility before being discharged. A given fraction of the heat recovered from the CHP is supplied to the leachate treatment system for increasing the whole energetic efficiency and environmental sustainability of the system. For these reason this landfill represents an innovative and integrated system and hence a relevant case study both from the environmental and energetic point of view. In the following the research was focused on the energetic aspects including all the main activities necessary for the management of the landfill.

Nomenclature

GHG	Greenhouse gas	OF	Organic fraction
η	Efficiency	σ	Standard deviation
LFG	Landfill Gas	W	Power output
LHV	Lower Heating Value	*Subscripts*	
MSW	Municipal Solid Waste	el	Electrical

2. Material and methods

The landfill analyzed in this study is located in central Italy and has a maximum authorized volume for waste disposal of about 1,500,000 m^3 that is a typical value for Italian landfills. The landfill can dispose mainly MSW (Table 1) together with a limited amount of special waste with features similar to MSW. It started operating in the 1995. The LFG collected is currently exploited in an existing combined heat and power (CHP) plant consisting of 6