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METHANE OXIDATION EFFICIENCY AND NMVOCs REDUCTION IN A FULL-SCALE PASSIVE BIOIFLTRATION SYSTEM FOR THE TREATMENT OF RESIDUAL LANDFILL GAS *

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Abstract

The aim of this study is to assess the abatement of Non-Methane Volatile Organic Compounds (NMVOCs) in a full-scale prototype (biowindow) constructed for the passive biofiltration of low levels of Landfill Gas (LFG). The prototype was built on an emissive hot spot of the capping layer at Le Fornaci di Monticiano Landfill (SI), an aftercare landfill site. NMVOCs emissions from landfills can cause unpleasant odors, can be toxic for human health and cause an important impact on the environment. As such, is important to characterize the LFG and evaluate the abatement efficiency of the technique adopted for the treatment of LFG. In this study, the composition of the LFG inlet the prototype was characterized in terms of NMVOCs and the dynamic chamber method was used to assess the concentration of NMVOCs emitted at the surface of the biowindow. Three monitoring campaigns were performed, and the methodology applied have permitted to evaluate the NMVOCs abatement and methane (CH_4) oxidation efficiency. Regarding CH_4 oxidation efficiency the results show an average maximum value greater than 95%, while NMVOCs efficiency abatement depends on the functional group of each compound, but the average efficiency is more than 90%.

Keywords: biofiltration, NMVOCs, oxidation efficiency, residual landfill gas

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1. Introduction

The management of low levels of Landfill Gas (LFG) is a central issue of the scientific community in the context of the waste management sector. After the entry in force of the Landfill Directive (1999/31/CE), the amount of biodegradable waste disposed in landfills was reduced and only pre-treated waste must be disposed in landfills. As such, the generation of LFG, produced by the anaerobic decomposition of the organic fraction of the municipal solid waste (MSW) is less in quantity and quality. Accordingly, the technical measures imposed by the Landfill Directive to control emissions of LGF can become technical inefficient and the LFG is vented to the atmosphere without treatment. Moreover, in Europe there are thousands of closed landfills, without any facilities for the management of LFG.

LFG is mainly composed by CH_4 and carbon dioxide (CO_2), both greenhouse gases (GHGs), and Non-Methane Volatile Organic Compounds (NMVOCs), that account for a minor part of the total LFG, but cause human health concern, unpleasant odor emissions and toxicological effects on the environment. When the content of CH_4 in LFG is below approximately 30% v/v, the LFG can be defined LGF with low calorific value (low CV-LFG) (EPA, 2010).

Biological CH_4 oxidation represents an innovative and cost-effective process to mitigate emissions of low CV -LFG (Bogner et al., 2007). Today, biofilter, biocover, biotarp and biofiltration trench are the main technologies studied to apply for the biological methane oxidation.

Many studies focus on the evaluation of CH_4 oxidation efficiency, on the suitability of the filter media (Huber-Humer et al., 2009, Huber-Humer et al., 2011, Scheutz et al., 2009), and on the major aromatic, sulphur and odorous compounds in the raw LFG and emitted at the surface of these biofiltration systems (Kim, et al., 2006, Kim et al., 2005, Scheutz et al., 2008, Capanema et al., 2014). However, only few studies analyze the composition of low CV-LFG in terms of NMVOCs and abatement of this trace compounds in a passive and full-scale prototype for the biological CH_4 oxidation, as a biowindow.

Biowindows, proposed by Kjeldsen et al (2007) are innovative technologies for the treatment of low CV-LFG in aftercare or closed landfills in which there is not a gas collection pipe network. A biowindow is directly builds in the cover layer of a landfill and the gas migrates in the system thanks mainly to the variation of atmospheric pressure and diffusion. The main objective of this study is to assess the CH_4 oxidation efficiency and NMVOCs abatement efficiency of a biowindow built at Le Fornaci di Monticiano landfill, an aftercare landfill site.

2. Case study

The location selected as case study is Le Fornaci di Monticiano landfill. The landfill has been closed by the landfill owner in 2001, before the entry in force of the Landfill Directive. At the landfill site, the LFG management system is composed only of vertical wells and flares with manual ignition, no more functioning because of the low quality and quantity of LFG produced within the landfill. Based on the outcomes of a preliminary field survey, seven emissive hot spots were identified, and, on each point, the existing LFG passive control system has been substituted by a passive biofiltration module. Briefly, each biowindow is made of a filter volume of about 5 m^3 with a filtering section of 4 m^2. The filter bed is made of two layers: a gravel layer for the homogeneous LFG distribution and a compost layer in which the microbial process occurs. The thickness of the compost layer is approximately 120 cm while the gravel layer is about 20 cm (grain size 15-30 mm). Sand in a volume ratio 5:1 has been added to improve compost structure. A geogrid was used to separate the two layers. The filter bed is contained in metal formworks that reinforce the whole module.

In this context, one biowindow (BW8) was investigated and three monitoring campaigns were performed to characterize in terms of NMVOCs the raw LFG inlet and emitted at the surface of the prototype. At the same time the CH_4 oxidation efficiency and NMVOCs abatement efficiency were assessed.

The campaigns were made in March 2017, August 2017 and March 2018. Materials and methods applied to characterize the NMVOCs in the raw LFG and emitted at the surface of BW8 are described in detail in Pecorini et al., 2017. The methodology proposed by Lee et al., 2018 is applied to evaluate NMVOCs abatement efficiencies while CH_4 oxidation efficiency is evaluated through the methodology proposed by Gebert et al., 2011 and described in detail in Pecorini et al., 2017.

3. Results and discussion

Table 1 shows the composition of LFG inlet BW8. Regarding the three monitoring campaigns, the average composition is 15±12.2 % v/v, 16.7±12.2% v/v 7.1±6.9 % v/v respectively of CH_4, CO_2 and O_2 that is typical of a residual landfill gas. A high variability of LFG composition was observed. This is due to many factors that affect the composition of LFG such as waste composition, components of the Organic Fraction of the Municipal Solid Waste (OFMSW) (Pecorini et al., 2012) landfilled, the age of the waste and waste management systems.

Table 1. LFG composition inlet BW8

LFG composition	*March 2017*	*August 2018*	*March 2018*
CH_4 [%v/v]	29.47	9.34	7.51
CO_2 [%v/v]	15.33	29.53	5.27
O_2 [%v/v]	7.04	0.23	13.98

Fig. 1 shows the results of the characterization of NMVOCs in the LFG inlet, emitted at the surface and NMVOCs reduction efficiency of BW8. In Fig. 1 the sum of the concentration levels of compounds belonging to each NMVOCs family find in the samples is showed. Regarding the classification of NMVOCs in the inlet LFG, aliphatic compounds are the dominant one and the most abundant are cyclohexane, n-butane, propylene and n-pentane (results not shown). This result is typical of a LFG with low calorific value as indicated by Parker et al., 2002.

H_2S is classified as the second prevalent compound and the concentration level is similar of those evaluated by J.-J. Fang et al., 2012, sampled from a gas well located in an older section of one of the landfills studied. Then, was observed an abundance of organ-halogen and aromatic compounds. The authors Kim et al., 2006 and Liu et al., 2016 indicate toluene as the most abundant compound in LFG, but in this study m,p,o-Xylene and 1,3,5-. Trimethylbenzene has the higher concentration levels, while toluene is ranking only third.

The concentration levels of alcohol, terpene, nitrogen and sulphur compounds were lower than the others. Dimethyl sulphide and methyl mercaptan, malodorous components, were found at appreciable but not very high concentration, respectively 21.4 e 8.1 $\mu g\ m^{-3}$. High values of standard deviation indicate high differences in concentration levels of NMVOCs find in the samples. These differences suggest that the emissions of NMVOCs is not only site-specific, but also other factors such as the variation of climate conditions (ambient temperature, atmospheric pressure), CH_4 and LFG load affect the process.

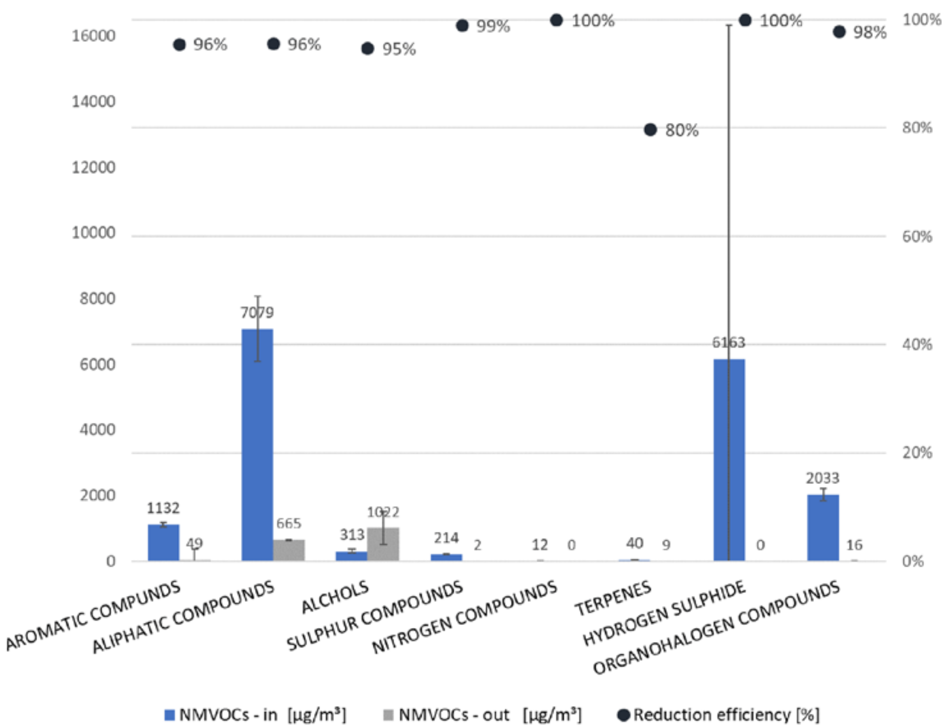
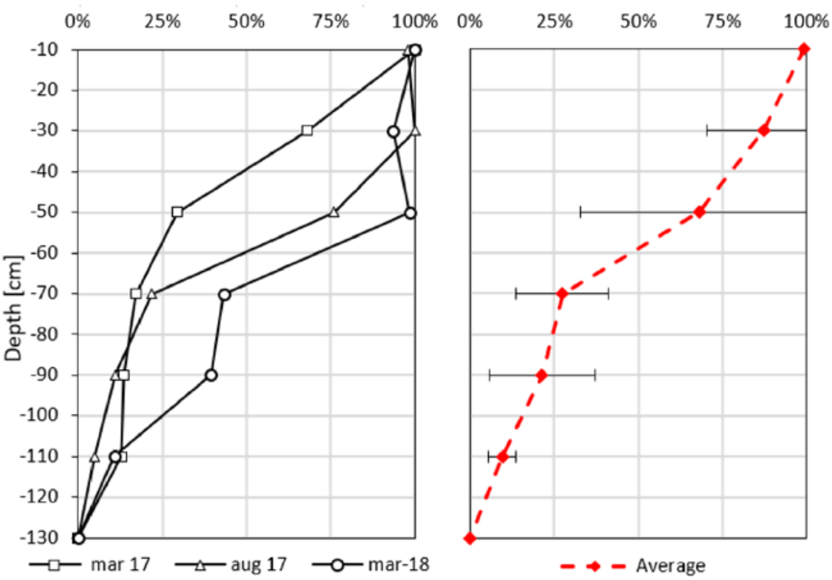


Fig. 1. Concentration levels of the NMVOCs present in the LFG samples and NMVOCs abatement efficiency of the passive biofiltration system

Concentration levels at the surface of BW8 are very low as shown in Fig. 1. NMVOCs reduction efficiency (black spots in Fig.1) is more than 80% for each family of NMVOCs. BW8 can completely remove nitrogen compounds and H_2S. Sulphur compounds are removed with an efficiency of 99%, while Capanema et al., 2014 indicates that biocovers made of sand and compost have an abatement efficiency respect to total reduce sulphur greater than 95%.

Fig. 2 illustrates the oxidation efficiency evaluated in each of the three monitoring campaigns in which was performed the NMVOCs screening. Fig. 2a) shows oxidation efficiency calculated along the gas sampling profile of BW8 in each monitoring campaign performed. At the bottom of the filter bed (130-70 cm of depth), the concentration of O_2 is too low, CH_4 oxidation process doesn't occur and CH_4 oxidation efficiency is less than 50%. Rising to the surface the concentration of O_2 increase and it is available to the methanotrophic bacteria that can oxidase CH_4 presents in LFG. As such, has been observed that CH_4 in completely oxidase at the surface of BW8. The CH_4 oxidation efficiency increases up to the maximum value of 100% in March 2017 and in March 2018. Despite of this result, during August 2017 the maximum oxidation efficiency was calculated at 30 cm of depth. This is probably due to the hot climate (over 40°C of the ambient temperature was registered during the sampling date in August, data not shown), that reduce the moisture content of the compost and minimize the bacterial activity in the upper layer. Fig. 2b) illustrate the average CH_4 oxidation efficiency regarding the three monitoring campaigns. The maximum value of oxidation efficiency is greater than 99% while the maximum standard deviation is calculated at 50 cm depth.



a) b)

Fig. 2. CH_4 oxidation efficiency of BW8: a) of each monitoring campaign b) average of the three monitoring campaigns

4. Concluding remarks

The composition of LFG in terms of NMVOCs and abatement efficiency was investigated. The concentration levels of the NMVOCs indicates that the LFG is typical of those find in the older sections of a landfill.

Passive biofiltration systems, especially biowindows, show to be effective technique for the reduction of concentration levels of many family of NMVOCs find in LFG. High CH_4 oxidation efficiency was observed even the high variability of CH_4 load inlet BW8.

Future works should focus on the influence of climate factors on the microbiological process.

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