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Optimizing Methane Recovery for Fuels: A Comparative Study of Fugitive Emissions in Biogas Plants, WWTPs, and Landfills

Daniel Gil-García [1], Marta Revuelta-Aramburu [1,2], Carlos Morales-Polo [1,2,*] and María del Mar Cledera-Castro [1,2]

1 ICAI School of Engineering, Comillas Pontifical University, 28015 Madrid, Spain
2 Research Group on Emerging Pollutants and Resource Recovery (gCEV), ICAI School of Engineering, Comillas Pontifical University, 28015 Madrid, Spain
* Correspondence: cmorales@comillas.edu

Abstract: How accurate are current estimation methods for fugitive methane emissions in methane-producing facilities, and how do they vary across biogas plants, wastewater treatment plants (WWTPs), and landfills? Based on this, the hypothesis posited in this study is that current methods significantly underestimate methane emissions, particularly in WWTPs and biogas plants, due to limitations in accounting for recovered methane and the reliance on general parameters such as the oxidation factor. To test this, a comparative analysis was carried out involving 33 biogas plants, 87 WWTPs, and 119 landfills in the Iberian Peninsula, comparing officially recorded data with estimates derived from our own calculations. Our findings confirm the lack of precision in current emission estimation methods, particularly for WWTPs and biogas plants, where factors like the omission of recovered methane lead to underreporting. This study highlights that WWTPs emit the largest amount of methane due to their organic material processing, exceeding emissions from landfills and biogas plants. In contrast, methods for estimating emissions in landfills are found to be more reliable. The results suggest that improving calculation methodologies, especially for WWTPs and biogas plants, as well as enhancing leak monitoring and methane recovery systems, is crucial to reducing the environmental impact of methane-producing facilities.

Keywords: fuel production; methane emissions; biogas plants; wastewater treatment plants; landfills; methane recovery; greenhouse gases

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1. Introduction

Greenhouse gases (GHGs) are currently one of the most significant environmental concerns due to their involvement in global warming. Among the complete list of GHGs, carbon dioxide and methane are the most common and well known [1]. CO_2 is the most abundant, since it is the most oxidized form of carbon that can be found and is generated in oxidation reactions involving carbon. For its part, CH_4 has a global warming potential 28 times greater than that of CO_2 within a time horizon of 100 years [2].

Anaerobic digestion or decomposition (AD) is a waste management process for biodegradable materials, generating biogas, a combustible gas product consisting mainly of CO_2 and CH_4, and a digestate. This stabilized residue can be used as a soil amendment. On an industrial scale, this biological process can be found in waste biomethanation plants dedicated to biogas production. Thus, these are presented as potentially emitting methane leakage facilities [3]. CH_4 from this sector (B) accounts for around 3% of global anthropogenic GHG emissions [4].

In Europe, landfills are the second largest anthropogenic CH_4 emission source after natural events [5], mostly due to fugitive emissions, accounting for around 7% of the global anthropogenic GHG emissions [6]. These fugitive emissions from landfills (L) are expected to increase by 25% in the next nine years [5], and come mainly from the spontaneous AD of