LAB-SCALE AND FIELD-SCALE STUDY OF SILOXANE CONTAMINANTS REMOVAL FROM LANDFILL GAS

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Abstract

We present in this paper the results of the field-testing at a California Landfill of a UV photodecomposition reactor (PhoR) used for the removal of siloxane impurities from landfill gas (LFG). PhoR technology was tested in the laboratory with simulated LFG and was shown to be very effective in oxidizing the trace siloxane compounds and to convert them into silica particulates [Divsalar et al., 2018]. The key objective of the field-test was to validate the ability of the PhoR system to treat real LFG in a practical setting. The field-scale PhoR proved again quite efficient in removing the siloxanes in the real landfill environment, with high siloxane removal rates attained at different concentrations. These positive findings have led us to propose a scaled-up PhoR system, competitive to conventional adsorption systems that can be practically applied in existing landfill plants to obtain high siloxanes removal rates without associated secondary emissions.

Keywords

Landfill Gas, Siloxane, UV Photodecomposition, Reactor Modeling,

Introduction

Because of its large methane content, biogas has been studied in recent years as a potential alternative renewable energy source. Although biogas is mostly composed of methane (CH_4) and carbon dioxide (CO_2), together with smaller concentrations of oxygen (O_2) and nitrogen (N_2), it also contains a variety of trace impurities known as the non-methane organic compounds (NMOC), which include silicon-containing compounds known as siloxanes. The presence of the NMOC in biogas creates technical challenges that presently hinder its widespread use as a renewable fuel for power generation. Siloxanes, in particular, have been shown to generate silica (SiO_2) microparticulates during combustion, which have been found to damage the equipment, and also present a potent threat to the environment, if released. To date, relatively little research has focused on the removal of siloxanes from biogas, which is the primary focus of this study. Currently, the most common techniques employed commercially for remediating siloxanes in biogas (including the most frequently encountered ones such as L_2 and D_4) are adsorption and absorption.

Although adsorption is, typically, an effective technique for the removal of trace contaminants from gaseous waste-streams, it is not all that effective for the clean-up of siloxanes because their concentration in biogas is, typically, quite low compared to those of the other NMOC. Reactive absorption processes require the use of harsh absorption agents (e.g., nitric

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acid and/or sulfuric acid), something that significantly increases the cost and technical complexity associated with these processes. Physical absorption techniques involve less toxic chemicals but, on the other hand, are not all that effective for the removal of light siloxanes (e.g., L_2) due to their high volatilities. Additionally, adsorption and physical absorption processes suffer from similar disadvantages which is the need for absorbent regeneration, than can reduce siloxane removal efficiencies over time.

The UV photodecomposition reactor (PhoR) is a simple and potentially cost-effective means, which was used in this study for remediating the siloxane pollutants in landfill gas and biogas. Single and integrated (with catalytic oxidizers) systems of UV reactors were utilized for the lab-scale and field-scale studies. For the lab-scale studies, two simulated landfill gas compositions were utilized, termed SLFG and SLFGV. They have the same fixed-gas content, but the latter contains, in addition, five NMOC compounds at ppm levels. Real LFG was used in the field studies.

Results and discussion

The feasibility of using the UV photodecomposition system for siloxane contaminants removal was previously proven in preliminary studies, and a US patent has been issued [Tsotsis et al. 2017]. Further studies were carried out in this project to investigate the effect of LFG flow rate, initial siloxane feed concentration and biogas type (simulated vs. real) on siloxane impurities removal. Our studies show that the siloxane conversion increases as the gas flow rate decreases, as expected. Also, there is no significant dependence of conversion on siloxane concentration. For instance, Figure 1 and 2 show the field-test results for L_2 and D_4 conversion as a function of retention time at different feed concentrations when a 41W UV lamp was used inside the PhoR.

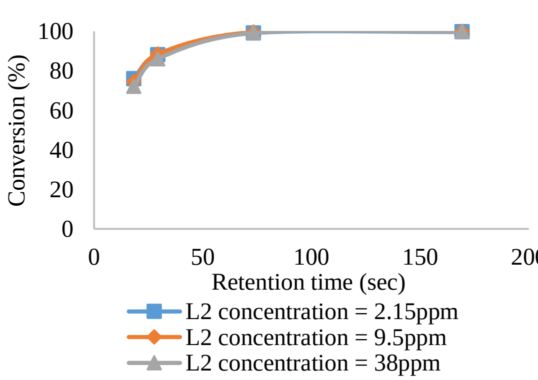

Figure 1. L_2 conversion as a function of retention time for different feed siloxane concentrations

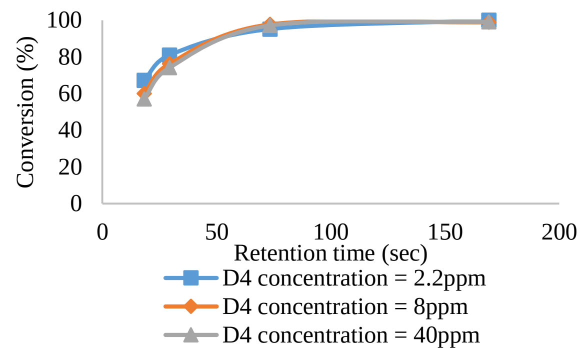

Figure 2. D_4 conversion as a function of retention time for different feed siloxane concentrations

Conclusions

Not only is high siloxane removal attained by the PhoR, but also other NMOC compounds undergo a photocatalytic decomposition reaction as well, and thus high conversions were also attained for those contaminants. The high conversions attained for siloxane removal using the photo-decomposition technique at a real landfill site as well as in the lab indicate the efficiency and advantage of using this method compared to more commonly used technologies for biogas clean-up. Higher linear siloxane (L_2) conversions compared to cyclic ones (D_4) were obtained for the lab-scale and field-scale studies. Oxygen has an important effect on the photodecomposition process. The higher the oxygen present in the system is, the more ozone is produced which, in turn, results in higher conversion of the siloxanes and of the rest of the NMOC compounds. 3-D reactor models were also developed in this research, and were shown to account accurately for all phenomena that take place inside the reactor. Using these models, reaction kinetic parameters were computed (by utilizing the non-linear fitting regression toolbox option in Matlab linked with ANSYS® Fluent) that can accurately describe the experimental data for mixtures of siloxanes in air as well as in the biogas.

References

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